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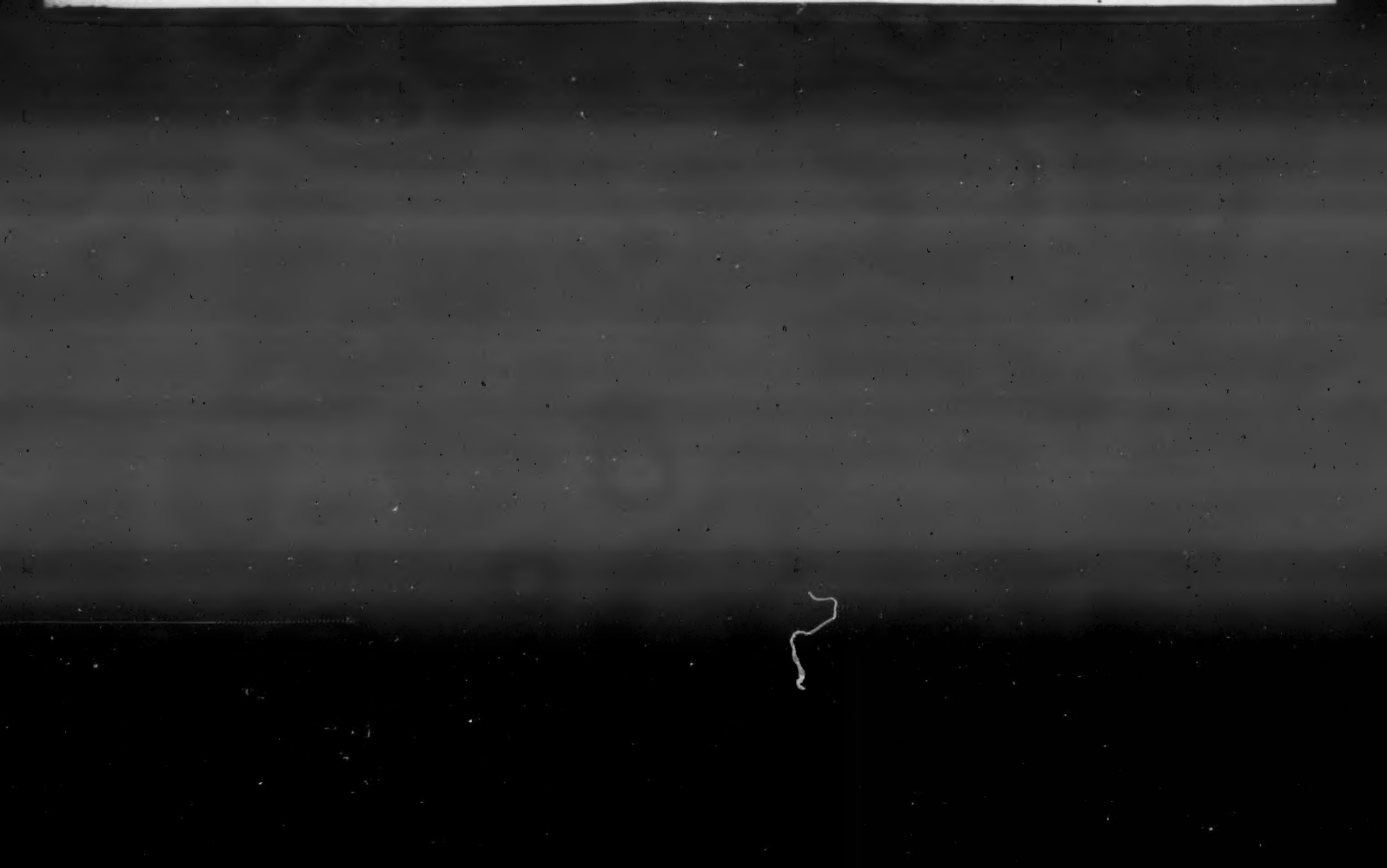

THE

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[THIRD SERIES.]

ART. XXVII.—*The relation between Wind Velocity and Pressure;* by H. ALLEN HAZEN.

FOR more than a century physicists have attempted a solution of the problem with regard to the relation between wind-velocity and pressure; yet the experiments tried by different observers and under varying conditions have often been contradictory and difficult to reconcile. Two methods of investigation have been very frequently adopted, the one by carrying a plate either in a straight line or in a circle, and the other by allowing a current of air to impinge normally upon the plate. The pressure has been measured by using delicate appliances on the plate; but it will be readily seen that there must be great uncertainty in such measurements, if made at the extremity of a long arm, and, moreover, the use of any attachment whatever to the plate would tend to dampen the effect we wish to measure, i. e. the plate would be restrained from following the actual movements imposed upon it by the accumulation or flowing off of the air from its front.

Borda's experiments.—Perhaps the most reliable of the earlier results are those by Borda in 1763. He used a kind of fly-wheel, with vertical axis and a horizontal arm a little over 7 feet in length. On the end of this arm he placed the flat plate,

or any other object, the resistance of the air against which he wished to learn, and observed the uniform velocities of the fly-wheel under the action of different weights. He used plates 9·59, 6·39 and 4·26 in. on the edge, and weights of 8·8, 4·4, 2·2, 1·1 and ·55 pounds, in generating velocities. The observations may be very satisfactorily united into the following formula:

$$p=(\cdot0031+\cdot00035c)\ SV^2$$

In which $p=$ pressure in pounds; C= contour of plate in ft.; S= surface in sq. ft.; V= velocity in miles per hour. This notation will be preserved throughout this paper. The formula may be converted into velocity in ft. per second by multiplying by $(22\cdot15)^2$.

Hagen's experiments.—By far the most careful experiments with a whirling machine were those of Hagen in 1873. The arm in this case was 8 ft. in length. The velocity ranged from 1 to about 4 miles per hour. The room seems to have been quite small, as, with the latter velocity, the air was set in feeble rotation. The plates ranged in size from 4 to 40 sq. in. area. He found, as in the case of Borda, that the pressure per sq. ft. increased with the larger plates. His formula is:

$$p=(0029+\cdot00014c)\ SV^2.$$

These experiments were conducted with so great care, and so complete an elimination of all apparent sources of error, that they alone were depended on by Prof. Ferrel in his recent discussion of this question. See Annual Report Chief Signal Officer, 1885, Part ii, pp. 314 and 407.

Experiments at Metz, France.—MM. Piobert, Didion and Morin, at Metz, used a plate of 10·764 sq. ft. area, allowing it to drop vertically a distance of nearly 47 ft. in a foundry. The times, spaces, and velocity of fall were measured electrically, and the following approximate pressure of the air was obtained:

$$p=(\cdot002+\cdot0035)\ SV^2.$$

To test the effect of the size of the plate, another series of results was obtained with the above plate, and another of $\frac{1}{4}$ its size. The larger plate required a little longer time in falling through any given space than the smaller, hence the pressure per sq. ft. upon it must have been greater than on the smaller. This is in the same direction as the results of Borda and Hagen, but the difference was very slight and the conditions were quite unsatisfactory. The short distance and time of fall preclude any but the most general conclusions.

Experiments in Washington.—In Nov., 1886, it was decided to make a short investigation on this subject. It was necessary to adopt the simplest and cheapest possible apparatus. At-

tempts were made, at first, to use a tricycle in calm weather. Plates were carried on different days and at varying speeds, but it was found, finally, that the resistance to be measured was so small, and the apparatus so sensitive that the jarring, even on the smoothest pavement, and very slight breaths of air, vitiated the results, and rendered the method unsatisfactory. The same may be said of experiments on a whirling machine, in the open air, used in connection with the pastime "hobby horses." In this case the arm of the apparatus, 12 ft. in length, was increased to 17 ft. by the use of gaspipe. The pressures were measured by the elongation of a spiral spring. The plate, suspended by delicate threads from an upright, was kept vertical by pulling on the spring and its observed elongation indicated the pressure exerted. In both these cases the greatest velocity attained was 12 miles per hour. In the latter case the experiments were interfered with by the effects of centrifugal action upon both the plate and the observer. The results may be expressed by the formula:

$$p = \cdot 005\ SV^2.$$

The plates ranged from 144 to 576 sq. in. area.

Experiments were next tried in a room 14 by 25 feet, and afterward, with the same apparatus enlarged, at the building of the U. S. Fish Commission, in a room about 50 ft. sq., but giving only 40 ft. clear space. The details of the latter apparatus will be given here. A heavy gas pipe, 34 feet in length, was suspended by two ropes from a beam in the attic, a hole having been cut in the ceiling of the operating room. The point of suspension was just below the swivel of a chain, and the ropes could be spread to any desired angle on the bar. The motive power was obtained by winding up the ropes one upon the other, by turning the lower part of the swivel, and the unwinding produced a most excellent, uniform, and steady motion. At the higher rates of speed it was found that the ropes were in danger of cutting each other by the extreme tension. This was obviated by inserting a rod of $\frac{5}{8}$ in. iron, and winding the two ropes upon that. The method of measuring the resistance was to allow the plates, suspended by delicate threads either 4 or 8 feet in length, to swing to various angles. The size of the angle was measured by looking on a scale having such large divisions that they could be read easily at the axis of the apparatus. At first it was proposed that the observer should sit at the centre of the bar and make readings of the scales, as he faced them, at any moment, but it was found that the whole apparatus, notwithstanding its weight of 350 pounds, was so delicate in its adjustments that slight movements of the hand in making a record were felt by the plate. It became necessary,

therefore, to substitute a heavy weight for the observer and make readings of the scale by standing at the centre and gradually turning so as always to face the scales. Four plates were used, two of them at 16 feet, one at 8, and the fourth at 4 feet from the axis of the apparatus. It will be seen that, if the total pressures were proportional to the square of the velocity, that at 16 feet would be just 16 times, and at 8 feet 4 times that at 4 feet. It was also possible, by having two plates at 16 feet, to test the effect of different sizes of plates under absolutely the same conditions, and this was frequently done, a plate of 16 sq. in. area being compared with one of 576 sq. in. If we take the main bar about $\frac{1}{4}$ the length of this just described, and the suspensions of the two plates at 16 feet, we shall have the smaller apparatus first used. The total pressure upon the plate, by theory, was equal to the weight of the plate multiplied by the tangent of the angle of deviation from the vertical. Careful experiment showed that, within the limits of the angle of swing employed, there were no differences due to the slightly diminished quantity of air meeting the plate with the greater angle. The reason for choosing this method of measurement may be of some interest. After coiling a large number of springs of varying degrees of sensitiveness and calibrating them vertically by the use of weights, after the manner of the Joly gravity apparatus, it was decided to test the accuracy of the calibration on the spring used horizontally by measuring the force necessary to draw out a weight suspended by a long cord. It was found that the calibration did not give the correct value for the force, although all the springs gave almost identical results. The force necessary, or the elongation of the spring, when the angle of the weight with the vertical was small, was too slight, and the contrary was true with larger angles, as compared with theory. It was then found necessary to calibrate the springs horizontally by using a pulley, and after that the two curves coincided very satisfactorily. It then appeared that it would be much better to do away with the spring entirely and simply let the plate act like a weight, and then measure the angle of swing. Making the suspending cords of different lengths did not appear to change the result. It was found that the angle of the suspending threads must be quite large, else the plate would take upon itself a wavy motion, twisting back and forth on the line which was its intersection with a vertical plane passing through its center, at right angles to the supporting bar.

One peculiarity in the results was the extreme sensitiveness of the plate; there seemed to be a gradual heaping up of the air in front of the plate as the rotation proceeded, and then a much more rapid falling away causing the plate to drop back. After

several turns the plate became somewhat steadier and showed a slightly less pressure, possibly owing to a slight following after of the air, produced by the motion of the plate. In order to determine the uniformity of the times of revolution, a chronograph was employed, the bar being made to record its own turns. One of these records is here given:

Chronograph Record of Revolutions.

No. of the turn.	Seconds.	No. of the turn.	Seconds.	No. of the turn.	Seconds.
1	4·8	9	3·9	17	3·9
2	4·5	10	3·9	18	4·0
3	4·4	11	3·9	19	3·9
4	4·3	12	3·8	20	4·0
5	4·1	13	3·9	21	4·1
6	4·0	14	3·9	22	4·0
7	3·9	15	3·9	23	3·1
8	3·9	16	3·9	24	4·2

This table shows that after the first 6 turns the motion became uniform and continued so for at least 14 turns. After a long series of observations the following formula was obtained:

$$p=(\cdot0032+\cdot00034c)\ SV^2.$$

There is a most remarkable and unexpected coincidence between this result and that of Borda, and this correspondence seems to indicate that there could hardly be any constant errors, as the apparatus was so entirely different from Borda's. It will be noted that Hagen's formula was derived after the total pressure had become uniform, and it may be said that nearly the same result would have been found after the first 15 or 20 revolutions of the above apparatus.

The later experiments with an arm of 16 feet developed the fact that there was no increase of pressure per square foot with the larger plates, as in the previous results, but that it was constant for sizes from 16 to 576 square inch area. The formula from these results was:

$$p=\cdot0034\ SV^2,\ \text{Rouse's experiments.}$$

All the results thus far, except those at Metz, were derived with whirling machines, and it is of interest to compare them with others made with an air current impinging upon the plate. Such, probably, are those of Rouse in the 18th century. His formula was as follows:

$$p=\cdot0049\ SV^2,\ \text{Thibault's results.}$$

In these experiments plates of 1·162 and 1·531 square foot area were exposed to direct wind pressure and gave the formula:

$$p=\cdot00475\ SV^2.$$

The value of the constant in seven of the published results ranged from ·0039 to ·0054. The mean of the seven agrees very closely with that of Rouse.

Recent Experiments.—Experiments have been tried in France on the resistance of the air to flat boards, suspended laterally from a train, movable on axles and counter-weighted. The results have been given in the Railroad and Engineering Journal for February, 1887. The train was run at increasing velocities and the instant was noted when the resistance of the air, preponderating, caused the lifting of the weight and reversal of the board. The resistance on a plate a decimeter square, in absolutely calm weather, was found to be ·52 kilogram, at a speed of 44·5 miles per hour. The data give:

$$p = \cdot 00535\ SV^2.$$

For other velocities the variation is sensibly as the square of the speed; and within practical limits the *extent* of the surface does not sensibly affect the result.

Theoretical formula.—Prof. Unwin in the "Encyclopædia Britannica," in the article Hydromechanics, at p. 517, gives the following formula for the resistance encountered by a thin plate moving through the air, or through an indefinitely large mass of still water, in a direction normal to its surface

$$R = f\,G\,S\frac{V^2}{2g}.$$

In this: R= total resistance, expressed in pounds, due to an excess of pressure in front augmented by an increase of pressure due to a partial vacuum in the rear of the plate; f= a coefficient to be determined by experiment; G = density of the fluid; S= surface of plate in square feet; V= relative velocity of fluid and plate in feet per second; g = force of gravity. For a plate moving in still fluid, f=1·3, and for a current impinged upon a fixed plane it is 1·8, whether the fluid be air or water. Prof. Unwin thinks this difference is, perhaps, due to errors in the experiment. Thibault, with plates of 1·17 to 2·50 square feet area, exposed to wind pressure, found f to vary from 1·568 to 2·125, the mean being 1·834. Using this value for f, and making the proper substitution in the above formula, we find by our notation,

$$p = \cdot 00496\ SV^2.$$

It will be noticed that Prof. Unwin's description of Thibault's researches differs slightly from that already given, presumably of the same experiments. The latter were taken from a translation of Morin's mechanics and may be in error. Prof. Unwin finds that all experiments with whirling machines have shown a steady increase of resistance per square foot with the

larger plates, and he thinks this is due to the centrifugal action which causes a flow of air outward across the plate.

It will be readily seen that there is a great difference between the results with small plates on whirling machines and those with direct wind pressure. The results with an arm of 16 feet, when compared with those of shorter arms, seem to indicate that the increase of pressure per square foot, with the larger plates, is due to centrifugal action, as suggested by Prof. Unwin, though it is probable that the effect is complicated, in almost all the results thus far, by the breaking up of the partial vacuum in the rear, thus tending to diminish the total pressure; and in a contrary direction, there is a tendency to increased resistance, especially in small rooms, from the fact that the air does not have a perfectly free escape to the rear, owing to the nearness of the walls. The constant for the arm of 16 feet is much less than that with the straight line motion, though it would seem as if it should be nearly the same. Possibly the partial vacuum in the rear of the plate is somewhat diminished, but more important, probably, is the low velocity employed, as with the four inch plate the velocity was seven miles per hour, but with the 24-inch plate (which had a resistance of ·33 pound) the maximum velocity was only four miles per hour. It is impossible from such results to reason to velocities ten times as great. Examining Thibault's results, we find two of them agreeing very nearly with those with the 16 foot arm, and it may be that they were dependent on a small wind velocity.

It seems necessary to carry on experiments at much higher velocities, but not with a whirling machine, though higher velocities with arms of 20 or 30 feet would undoubtedly give interesting results. The most feasible method would seem to be with a locomotive pushing two or three platform cars loaded with iron, the plates or other resisting forms to be exposed on the front car. By this means all interference from the locomotive or train would be obviated, and it would be easy to obtain results up to 40 and more miles per hour.

Conclusions.—1st. In obtaining the relation between wind pressure and velocity, the use of whirling machines with arms much less than 16 feet (radius) will tend to give unsatisfactory results, owing to centrifugal actions and to irregularities in the resistance of the air due to the formation of eddies, etc., especially in small rooms.

2d. The increase of total pressure per square foot, with the larger plates, as found by so many experimenters, is mostly due to the shortness of the arms employed, and disappears with an arm of 16 feet and in straight line motion.

3d. For velocities up to seven miles per hour with small

plates, and up to four miles per hour with larger plates, the relation between the pressure and velocity may be expressed by the formula,

$$p = .0034\ SV^2.$$

In this, p=pressure in pounds: S=surface in square feet: V=velocity in miles per hour.

4th. Experiments are much needed, with larger plates than two feet square, with bodies of other forms, and with high velocities by a straight line motion.

No attempt has been made in this paper to give a summary of anything more than what appeared to be the better class of results in this field. It is believed enough has been given to show which results are the more reliable, and how much necessity there is for further research.

Experiments with an anemometer.—One of the more important questions in connection with the use of Robinson's anemometer is the determination of the relation between the velocity of the wind and that of the cups. This relation has been assumed to be about 3, i. e., three times the velocity of the cups equals that of the wind. Some experiments in England with large anemometers as compared with smaller, have shown that if the former have a velocity of 2·5, the smaller would need a coefficient about a fifth larger to give the true velocity. The earlier anemometers used in this country were rather clumsy and unsatisfactory. A form was devised by Lieut. Gibbon (Signal Service), after experiments with an electric register of the actual revolutions, and a comparison with that form of wheel register which gave the result nearest to that of the electric count. This form has never been tested for its coefficient, so far as can be learned, hence a few observations were made on the 16 foot arm. The anemometer used was nearly new, having been run only 1,500 miles, was carefully oiled and in most excellent condition. The cups were 4 inches in diameter, and their distance from the axis 6·72 inches. The highest velocity attained was 12 miles per hour. The values of the coefficient in five sets were 2·92, 3·06, 2·84, 2·98, and 2·92, giving a mean 2·94 instead of 3·00, the one now in use. It should be noted that, intentionally, there was introduced a tendency toward a too small value, for, after the cups had acquired a momentum, toward the end of the experiment, the bar was stopped rather abruptly, but the cups were allowed to come to rest of their own accord. Experiments on this question are still needed with a rectilinear motion and with much higher velocities.

Washington, April 20, 1887.

Art. XXVIII.—*Is there a Huronian Group?* by R. D. Irving.

[Continued from page 216 of last number.]

IV. Deciding that the type Huronian is a true group is a very different matter from concluding that all rocks which have been called Huronian in other regions are the geological equivalents of the type series. On the contrary, even in the Lake Superior region, and by members of the Canadian Survey itself, there have been referred to the Huronian most diverse formations. Some of these seem properly enough so referable; others as surely are not so referable, while as to the reference of still others there must remain very much doubt. A discussion of those correlations which have been attempted between the type Huronian and the rocks of distant and always disconnected geological basins would be of little utility. Unsupported lithological evidence only is available for such correlations, and, in point of fact, with most, if not all of those who have attempted these distant correlations there has prevailed a most singular misapprehension as to the real nature of the type or original series. For this misconception Dr. T. S. Hunt seems to be mainly responsible, he having steadily represented the type series to be a truly crystalline one, and as composed of highly folded crystalline schists, mainly chloritic slates and schists.* *Yet there is no such series of rocks in the original or type area*, whatever may be true of other regions whose rocks have been called Huronian.

Not to concern myself then with these distant correlations, in which I am able to feel but little confidence, I wish next to consider briefly how far the rocks of other districts in the region of Lakes Huron and Superior may be correlated with the type Huronian.

For the establishment of such correlations we have of course no fossils, and must depend on the lithological characters and subordinate stratigraphy of the rocks whose reference to the type series is to be discussed, as also on their structural relations to adjoining rock groups. There is good reason to believe that in the region which stretches from the north shore of Lake Huron to the Mississippi River we are dealing with one geological basin, so far as the rocks which I take to be the equivalents of the type Huronian are concerned; in other

* "A great series of chloritic slates and conglomerates with interstratified greenstones, quartzites and limestones," Azoic Rocks, p. 70; "group of chloritic slates with greenstones and quartzites," ib. p. 72; "the younger and unconformable series of crystalline rocks found on the shores of Lake Huron," ib. p. 72; "the contrast between the highly disturbed condition of the former [Huronian] and the broad folds and gentle dips of the Montalban," ib. p. 215.

words, there is good reason to believe that all of these areas were once connected, the connections having since been removed by erosion. Hence the correlation of these different areas by lithology, stratigraphy and structural relations to adjoining groups is not so entirely unlike the use of these same criteria in tracing one of the fossiliferous groups from point to point.

Proceeding westward now from the type Huronian area, all the pre-Cambrian rocks are concealed, either by the waters of Lake Superior or by the overlying horizontal formations of the eastern part of the Upper Peninsula of Michigan, until the vicinity of Marquette, on the south shore of the lake, is reached. Here a belt of much crumpled, generally steeply inclined and partly schistose strata reaches the lake coast, with a width on the shore line of about five miles. The coast of the lake here has a nearly due northerly trend, facing eastward. The course of the rock belt referred to is at right angles to this, that is, it lies east and west. Followed westward the belt is found at first to expand to a width of some twelve to fifteen miles, and then to contract again, until at the eastern end of Lake Michigamme, thirty miles west of Lake Superior, it is little more than two miles wide. Still farther west it expands over a large area, whose limits can hardly be said to be as yet determined.

North and south of this belt are large areas of granitic and gneissic rocks. Two widely divergent views have been held with regard to the relations of these granites to the schists between them. The earlier writers on the region, and especially Messrs. Foster and Whitney, in their classical report, held that the granites were of eruptive origin, and of a date subsequent to the formation of the various stratiform rocks, whose crumpled and disturbed positions these geologists were disposed to assign to the eruption of the granite masses on either side of the trough. Later, on account of the arguments of Kimball, Murray, Brooks, etc., the view came to be generally held that the granitic and gneissic rocks represented the ancient Laurentian basement, upon which *all* of the stratiform or Huronian rocks were deposited unconformably; that, the whole region having been subsequently affected by a lateral pressure, the sedimentary rocks were pushed into folds, and that the granitic rocks on either side were brought to the surface by denudation. Recently the older view of Foster and Whitney has been advocated by Dr. M. E. Wadsworth* and Dr. C. Rominger,† both supporting it by an appeal to intrusions of the schistose

* Bulletin Mus. Comp. Zool., vol. vii, No. 1, 1880.
† Geological Survey of Michigan, vol. iv.

rocks by the granite. It is true of course that these granitic intrusions might be in part quite independent of, and of later date than the great granitic masses; but, as Dr. Rominger argues, and as our own observations have abundantly shown, these intrusions of the schists along their contacts with the granite are so plentiful in certain parts of the region that it seems necessary to conclude that such invaded schists are older than the great granitic masses themselves. On the other hand, we have found certain of the contacts of the stratiform rocks with the granite to present admirable examples of basal conglomerates, the granitic and gneissic rocks having evidently been beaten upon and broken down by the sea in which the other rocks were laid down.

These entirely contradictory appearances seem, however, to find a very simple explanation in the view that the stratiform rocks themselves are, in fact, made up of two entirely distinct sets;* an *older* series of very intensely altered and crumpled true crystalline schists, in the main of a greenish color, which are invaded intricately by the granite at their contacts with it; and a *newer*, feebly altered, mainly fragmental series, whose contacts with the granite and the schists of the older basement are such as to render the intervening structural break very evident. The contrast between these two sets of stratiform rocks as to degree of alteration, and as to the penetration of the one set by the granite while the others show no such penetration, was partly realized by Dr. Rominger, and is plainly stated in his report on the northern peninsula of Michigan, in which, however, he yet regards the granite masses as newer than all the stratiform rocks of the region, the high degree of alteration of the schists penetrated by them, as compared with the smaller degrees of alteration of the higher strata, being explained by the greater proximity of the one set to the granite. In the same report Dr. Rominger shows, however, that the relatively unaltered strata often come directly in contact with the granite, in which case they present a peculiar appearance suggesting to him a slighter alteration by contact with the eruptive masses. The peculiar granitoid quartzites which he takes to have been produced by the metamorphosing action of the granite are plainly, however, merely detrital derivatives from the granite, and often run into coarse bowlder-conglomerates, as Dr. Rominger himself now realizes and states.† However, neither he nor any other writer on this region seems to have realized heretofore that the clue to its geology lies in the separation of the stratiform rocks into two entirely distinct and mutually discordant series.

* As first suggested by myself in 1883, (Fifth Annual Report U. S. G. S., p. 190) and more definitely announced in 1884.

† Unpublished MS. report on the Geological Survey of Michigan, 1884.

The proofs of this distinctness are analogous to those which establish the separateness of the type Huronian, of Lake Huron, from the adjoining crystalline schists, viz: (1) a general lithological contrast between the two series concerned, the one being mainly but little altered, the other highly crystalline and schistose; (2) visible discordances in a few places on the contacts of the two sets of rocks; (3) the penetration of the lower strata by granite veins and masses which fail to penetrate the higher detrital rocks, but on the contrary have yielded fragments to them; (4) the development of true basal conglomerates at the contacts of the two series; and (5) the fact that the higher detrital rocks are in contact with different members of the lower series.

Nevertheless there are presented here some differences from the conditions observable on the north shore of Lake Huron, which serve to obscure the true relations of the different rocks. The placing together of all of the stratiform rocks of the Marquette belt by most geologists is not at all to be wondered at, for here the newer detrital rocks have been subjected to a much greater lateral pressure, and are consequently much more highly inclined and closely folded; besides which this closer crumpling has at times developed a tendency to a transverse cleavage accompanied now and then by the development of some of the micaceous minerals which are so frequent accompaniments of pressure metamorphism. Thus the evidence under the first of the heads just named is in part obscured, more especially through the development from fragmentals of certain mica-schists, though the essential lithological differences between the two sets of rocks become distinct enough on closer inspection.

A more important obscuration of original conditions applies to the evidence under the second head. Discordances are very plainly to be seen in a few places,* and perhaps in general the higher series lacks the high inclinations of the lower; still there are many places where its inclinations are very high, and where the common pressure, to which both underlying schists and overlying detritals have been subjected, has made them nearly or quite parallel. This apparent obliteration of unconformity is yet more marked in some of the districts subsequently to be noted. To render the case still more difficult of comprehension, the denudation which has so deeply truncated the region has occasionally brought to light within the area occupied by the newer detrital strata patches of the older schistose basement; which patches, sometimes completely surrounded, or bordered closely on either side by the newer fragmentals, it has seemed necessary to regard as parts of the same

* As for instance on the N.W. ¼ of sec. 1, township 47, range 24 west, south of Marquette.

formation with them. The matter has been yet further complicated—though this difficulty mainly disappears on microscopic study—by a resemblance, partly close and partly only macroscopic or very vague, between certain of the older schists that have been produced by the intense squeezing and alteration of some sort of basic eruptives, and certain interleaved basic eruptives of the upper series. Again, some of the later basic eruptives have intruded indifferently the detrital areas and those of the older schists. Notwithstanding these difficulties, and the fact that there may be with regard to some particular exposures doubt as to whether they should be referred to one or the other series of rocks, it remains sufficiently evident that there are the two distinct sets of rocks in the Marquette region.

The *upper* series is mainly composed of detrital rocks usually little more altered than in the Lake Huron Huronian; the most abundant being quartzites. These are of various phases, ranging from the most vitreous quartzite to only slightly indurated sandstone; but all are genuine fragmental rocks. A clayey admixture is often present, and then at times pressure has developed a schistose structure and a secondary sericitic ingredient; but even in this case there is no difficulty whatever in detecting the essentially fragmental character of the rock. By increase of this clayey ingredient we have a gradation into the clayey shales and slates, which form the next constituent of the series in order of abundance. These present many phases, ranging from arenaceous to earthy in texture; being at times cross-cleaved and again not so, when they are little more than clay shales. They include also some very highly carbonaceous kinds. Next to the detrital rocks in importance, and presenting often gradation phases into them, is a series of what we may speak of as chemical sediments, though these have often undergone very great changes since their first deposition. Here belong the various calcareous and dolomitic rocks, the cherty or jaspery ferruginous schists and iron ores, and the actinolitic ferruginous schists. Most, if not all, of these ferruginous rocks have been derived from bedded iron carbon-

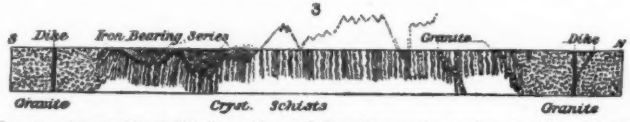


FIG. 3.—Generalized ideal section of the Marquette region in the vicinity of Marquette, showing the relations of the younger detrital rocks to the older granite-invaded schists. Scale, 2 miles to the inch.

ates by a process of silicification, as I have endeavored to show elsewhere, the unaltered or little altered iron carbonate at

times remaining in considerable bodies. Besides these two classes of sediments, or alteration derivatives from sediments, there are included also considerable thicknesses of diabasic greenstones in the shape of eruptive sheets. These are of

FIG. 4.—Generalized ideal section of the Marquette region in the vicinity of Ishpeming. In part after Brooks. Scale, 3 miles to the inch.

course irregularly distributed, being almost absent on some sections, and especially abundant on others, as for example on the Ishpeming section herewith. West of the area mapped, in the vicinity of Lake Michigamme, micaceous slates and micaceous quartzites make up a considerable thickness in the uppermost horizons of the series. These are often deserving of the name of mica-schist, approaching very close to if not quite reaching, the character of a genuine crystalline schist; but they run into kinds that are plainly detrital even to the naked eye. They have apparently been produced, as have the mica-schists of the Penokee region, by metasomatic processes, from detrital rocks holding much fragmental feldspar; but in this case, unlike that of the Penokee country, there has been strong lateral pressure involved and something of a genuine foliation has been produced. These schists and slates do not seem to be persistent, i. e., they are represented stratigraphically in other portions of the district by unaltered detrital rocks.

The accompanying map* and sections will serve to show the distribution and relations of the granite, older schists and younger iron-bearing series, for a distance of some five and twenty miles westward from Marquette. Since the idea of a separation between the older and newer rocks receives so great support from the occurrence of basal conglomerates, I have indicated on the map by letters the points at which the most unmistakeable occurrences of this kind have been met with, omitting all cases about which there seemed to me to be any question. It will be observed that the places indicated furnish points on each side of each of the detrital areas. In one case, as for instance, that on the east line of Sec. 2, T. 47, R. 25 W., we have merely a fine detritus from the contiguous granite; but in most cases large blocks and pebbles of granite, gneiss

* This map is not here reproduced. It was a large outline geological map, in colors, of townships 47, 48 and 49, ranges 25, 26, 27, 28, in Michigan, drawn to a scale of 1·5 miles to the inch, and showing the distributions of (1) the detrital iron-bearing rocks, (2) the older schists, and (3) the granite which invades the older schists at its contacts with them.

and schist occur in the slate or quartzite at the contact. The occurrences on the S.E. ¼ of Sec. 29, T. 48, R. 25 W., only about three miles west of Marquette, and those in Sec. 22 and adjoining sections of T. 47, R. 26 W., south and southwest from Goose Lake, are very striking; but possibly those in sections 8 and 19 of T. 49, R. 28 W., in the vicinity of Silver Lake, are yet more so. In this vicinity the older rocks, consisting of granite and schists involved with one another in such a way as to render irresistible the conclusion that the granite has intruded the schists, form a bold range sloping abruptly down to a lower area occupied by the softer detrital rocks. At the foot of the granite range the detritals, in contact with the granite and schists, are found crowded with fragments of both, of all sizes, up to pieces several feet across. The fragments are partly angular, lying in a breccia against the granite, and partly well-rounded. Since the granitic fragments represent a rock which, according to the present state of lithological science, could only have formed at great depths, and since the schists, whatever their first origin, must have received immense alterations by pressure before yielding fragments, we are forced to believe in a period of extended sub-ærial erosion intervening between the times of first formation of the older and newer rocks.

If we proceed in a direction southward from the Marquette region, we traverse great areas underlain by the granites, gneisses and schists of the older formation, but when the Menominee River is reached, at the boundary of Wisconsin and Michigan, we have crossed also at least four distinct belts occupied by the rocks of the newer or iron-bearing series. According to the mapping of the Michigan geologists these several belts merge, farther westward, into a single extended area of the iron-bearing series. It seems certain that this formation has a wide spread in that direction, but just what the relative extents of the older and newer rocks in this direction are, remains to be shown by further exploration. Of the several belts crossed by a line running south from the Marquette

FIG. 5. Generalized ideal section of the Menominee Iron Region. Scale, 3 miles to the inch.

belt to the Menominee River, that one skirting the Menominee River on its northern or Michigan side and run-

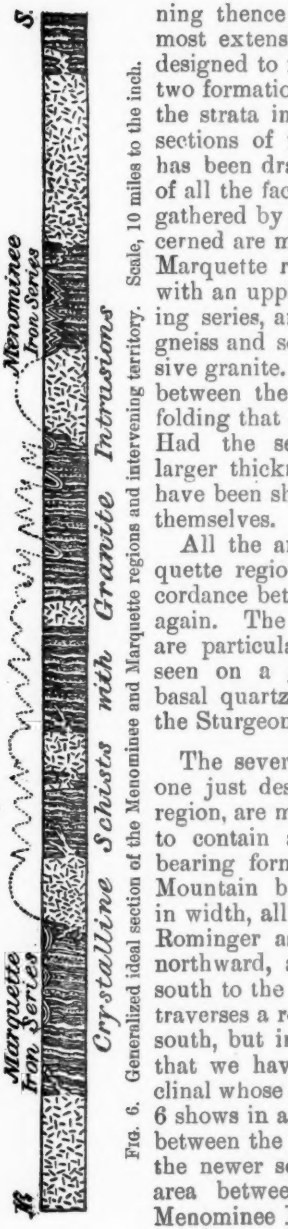


FIG. 6. Generalized ideal section of the Menominee and Marquette regions and intervening territory. Scale, 10 miles to the inch.

ning thence north of west into Wisconsin, is the most extensive. The accompanying section is designed to represent the general relations of the two formations and the nature of the folding of the strata in this region. As in the case of the sections of the Marquette region, this one also has been drawn to a scale after a careful study of all the facts hitherto published, and of those gathered by ourselves. The two formations concerned are manifestly identical with those of the Marquette region. We have here again to do with an upper, relatively little altered, iron-bearing series, and a lower, deeply altered series of gneiss and schists with immense areas of intrusive granite. The principal point of difference between the two regions lies in the much closer folding that the Menominee rocks have received. Had the section been made farther west, a larger thickness of the Huronian strata would have been shown, and other folds would present themselves.

All the arguments that applied in the Marquette region in favor of the existence of a discordance between the two formations, apply here again. The basal conglomerates of this series are particularly finely developed, and may be seen on a grand scale at the contact of the basal quartzite with the granite at the falls of the Sturgeon River.

The several belts that intervene between the one just described and that of the Marquette region, are much narrower, but nevertheless seem to contain as great a thickness of the iron-bearing formation. In the case of the Felch Mountain belt, which does not exceed a mile in width, all of the strata are described by Dr. Rominger as dipping at a high angle to the northward, and in crossing the belt from the south to the north, after passing the middle, one traverses a repetition of the belts crossed farther south, but in an inverted order. It would seem that we have to do here with a case of a synclinal whose sides are folded close together. Fig. 6 shows in a general way the supposed relations between the older rocks and the several belts of the newer series in the relatively little known area between the Marquette region and the Menominee River.

Passing now over a good deal of intervening territory, where the same two formations, however, continue to display themselves, I ask your attention next to the Penokee region of Northern Wisconsin and Michigan.

Here we find a most notable instance of an unconformity between a series of highly tilted but unfolded strata above the break, and a deeply folded series below. Indeed, there are in this region two striking stratigraphical breaks; one between the iron-bearing series and the folded gneissic formation to the south of it, and another between the unfolded but highly inclined iron-bearing series and the equally highly inclined Keweenaw series to the north. The accompanying map and sections* show the distribution and structural relations of the several formations and the several principal kinds of rock in this region. The Keweenawan and iron-bearing rocks both being highly inclined, the map is in fact what the vertical section is where the upper strata of an unconformity are essentially horizontal. The region is one which is only now beginning to be at all easy of access and it is still in the main covered with a dense forest growth. Notwithstanding these difficulties, and the further difficulty that in places the drift-covering is considerable, the general structure of the region has been by a great deal of painstaking labor pretty thoroughly worked out.

The lower one of the two unconformities of this region, i. e. that between the gneissic formation on the south and the iron-bearing series next north of it, is established by the same phenomena as those appealed to in the case of the region of Lake Huron. These are (1) the traversing of the lithologically distinct areas of the older or basement formation by the continuous belts of the higher series, as is most beautifully shown by the accompanying map; (2) the intersection of the schistose rocks of the older series by granite masses and areas which have yielded fragments to the higher series; (3) the occurrence in the higher series of fragments derived from the stratiform members (gneiss, mica schist, etc.), of the lower complex, these fragments occurring in beautifully developed basal conglomerates at the contact of the two sets of rocks; (4) the striking lithological contrasts of the two sets of rocks, the bedded members of the lower set having arrived at a nearly complete

* Not here reproduced. The map displayed when the paper was read was a colored one some twelve feet in length, showing the distribution of the iron-bearing rocks, the older schists, the granites invading these schists, and also in part of the Keweenawan Rocks of the region. This map with its accompanying sections, has already been published in a reduced form in this Journal for April, 1885. In a very much improved form it will appear also in the seventh annual report of the U. S. Geol. Survey, and in a forthcoming memoir on the Penokee-Gogebic region.

re-crystallization, while the upper series is composed mainly of but little altered fragmentals; (5) the highly foliated, folded and contorted condition of the lower rocks as contrasted with the unfolded and unfoliated condition of the higher. Any one of these would alone raise a strong presumption in favor of the existence of a great break at the junction of these two series of rocks; together they seem to amount to a demonstration of chronological distinctness.

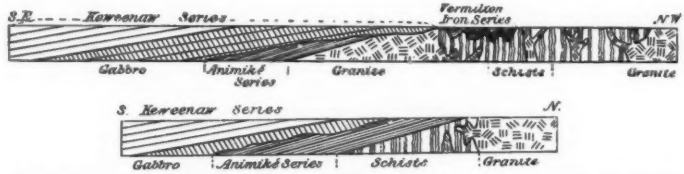
North of the narrow belt of country occupied by the iron-bearing series in this region, and all the way to the shores of Lake Superior, the rocks of the Keweenaw series are at surface, with the exception of a belt of country in the vicinity of Chequamegon Bay, which is underlain by the Potsdam sandstone, and a small area in the vicinity of the Presqu'Isle River, which is again occupied by the same formation. This sandstone, as is well known, traverses the upturned edges of the Keweenaw series in many places. It will not be possible now for me to review the nature and general structural characters of the Keweenawan rocks of this region. I can only say that the series consists of a great succession of eruptive flows, alternating with which are beds of detrital material, and following which is an immense thickness of sandstone. In the vicinity of the iron-bearing rocks these layers stand at high angles, and present in strike and dip a general conformity with the layers of the iron series itself. But a closer inspection renders it evident that the upper surface of the iron-bearing series has suffered a deep erosion previous to the spreading upon it of the great flows of which the lower portion of the Keweenaw series is made. This is shown by the very striking manner in which these flows are found in contact with all members of the iron-series as the contact line is followed from east to west.

Thus in the Marquette, Menominee and Penokee districts there are great discordances between a *lower* set of gneisses and other crystalline schists, intruded by granite, and an *upper* set of detrital rocks, carrying iron. In all three districts, moreover, the two sets of rocks seem so manifestly the same, being, indeed, very probably directly continuous through all, that we can hardly doubt that in all of these districts we are dealing with the same discordance. Above the uppermost of these series succeeds the great Keweenaw complex, while the Potsdam sandstone traverses indifferently the eroded edges of all three of these groups of strata.

If now, grouping these three districts in one region, we compare their succession with that of the Lake Huron region, we find such a striking similarity as to the relations and natures of

the members of the successions in the two regions, that little doubt can remain as to the equivalency of these members, each to each. In each region we start with a great basement complex of crystalline schists, gneiss and granite, upon whose immensely denuded upper surface reposes a great quartzitic and slaty detrital group, carrying sheets of chemically deposited iron and lime carbonates. In each region this is succeeded in turn, but with an intervening discordance, by the great Keweenaw series; while above this again follows the Potsdam sandstone.

V. I will next ask your attention to the relations borne by the so-called Animiké series to the older schists and granites of the region north of Lake Superior. These relations furnish us with an excellent instance of an unconformity in which the upper series has been tilted into an inclined position since its original accumulation, but in which the amount of tilting has not been great. In other words it is a case where the conditions are not greatly different from those obtaining when the upper formation above an unconformity has remained horizontal.



FIGS. 7 and 8.—Generalized and partly ideal sections of the northeastern part of Minnesota. Scale, 16 miles to the inch.

The accompanying map and sections show* in a general manner the geology of this region as known to date. Since this map is in large measure based on hitherto unpublished material, and since the geology of the area it represents has been heretofore, so far at least as the interior is concerned, largely conjectural, it is desirable that I should give here somewhat more of an account of the structure of this region than would otherwise be necessary.

* The sections only are here given, on a greatly reduced scale. The map displayed to the Academy was a large colored one, drawn to a scale of four miles to the inch, of all of that portion of the United States north of Lake Superior, and east of the upper Mississippi; showing the distributions of the Potsdam sandstone, of the Keweenaw series and of the great gabbro at its base, of the Animiké series, of the Vermillion Lake iron-bearing rocks and of the older crystalline schists, with the great granite and gneiss areas whose contacts with the schists appear to prove the former the newer rocks. This map, embodying the latest geological and geographical information, is now in press for the Seventh Annual Report of the U. S. Geological Survey.

The latest formation of the region is the *Potsdam sandstone*, which shows in the extreme southwestern corner of the area mapped, in the vicinity of the St. Louis River, between Fond du Lac and Thomson, Minn. The sandstone, here of a generally reddish cast, and with a slight easterly dip, may be seen directly overlying a series of folded and cleaved slates belonging in the upper part of the Animiké series, as subsequently explained. The contact of this sandstone with the Keweenawan rocks, which are largely displayed in the vicinity of Duluth, is concealed; but in Douglass County, Wis., at a distance of ten or fifteen miles southeast from Fond du Lac, the sandstone may be seen in very distinct unconformable abutment against the Keweenawan diabases of that district. Farther east the entire coast of Lake Superior, to within two miles of the mouth of the Montreal River, on the boundary line between Michigan and Wisconsin, is formed of the same sandstone in a horizontal position.

Unconformably beneath the Potsdam sandstone comes next the great *Keweenaw series*, which in this region reaches an aggregate thickness of upwards of twenty thousand feet, the layers being mainly of an eruptive origin, but also in part of a detrital nature. The upper detrital division* of the Keweenaw series is, however, not represented in the region, being buried here beneath the waters of Lake Superior. So far as the coast line of the lake is concerned, the characters and divisions of the Keweenawan rocks there displayed, I have set forth elsewhere.† Much new material has since been gathered with regard to these rocks in the interior of this region, but I will take the time now only to note their general flat lakeward dip,‡ the concentric and crescentic curves of the outcrops of the beds or groups of beds—the highest layers appearing on the Minnesota coast about midway its length—and the immense development of coarse grained, stratiform olivine-gabbro at the base of the series. These gabbros are the surface-rocks over an area in the interior some 125 miles in length from northeast to southwest, 25 miles in greatest width, and considerably more than 1,000 square miles in extent.

Next in downward order comes the *Animiké iron-bearing slaty series*, whose relations to the adjoining formations it is now designed especially to set forth. These Animiké rocks are exposed in four distinct areas, one of which is separated from the others by an overlap of the great gabbro which forms the base of the Keweenaw series. The others are separated

* See Monog. U. S. G. S., vol. v, pp. 152 and 266.

† Copper-bearing Rocks of Lake Superior, Monographs of the United States Geological Survey, vol. v, pp. 260–328 and Plates I–III, V–XV, XXVI, XXIX.

‡ Monog. U. S. G. S., vol. v.

from each other, so far as known, by drift covering only. The first of these areas is that which, with its principal development in Canada, along the shores of Thunder Bay, crosses into the United States in northeastern Minnesota, the national boundary line being within this formation from the outlet of Gunflint Lake eastward to the eastern extremity of Pigeon Point. Around Thunder Bay the rocks of this series, which are chiefly black slates, greywackes, and argillaceous quartzites, with interstratified diabase and gabbro layers, are exposed on a large scale. Immense dikes of gabbro and diabase also penetrate these layers, the gabbro dikes, which are at times several hundred feet in thickness, being noticeably much closer in character to the great gabbro at the base of the Keweenaw series than to those gabbros which are interleaved with the Animiké slates.

In the vicinity of Thunder Bay the Animiké rocks are often nearly horizontal, but show a general tendency toward a south-eastward inclination. As the formation crosses into United States territory it shows more marked inclinations, whose amounts average probably about ten degrees, though at times less than this, and again reaching as much as twenty degrees. As already said, the national boundary line is situated within this formation from the mouth of Pigeon River to Gunflint Lake, but on the north side of the latter lake, and again to the north of the next lake to the east, called North Lake, the unconformable abutment of the Animiké series against an older formation of granite and schists is very handsomely shown. The actual contact of the two formations is not seen, but the exposures approach to within a few feet of each other, and their relative attitudes are such as to leave no question whatever with regard to the unconformity. Not only is this shown by the vertical position of the schists as contrasted with the flat inclinations of the slaty series, but also by

FIG. 9.—Section across Gunflint and Loon Lakes, on the national boundary line. Scale 1½ miles to the inch. Designed to show the relation of the Animiké series to the older schists and granite, and to the newer Keweenawan gabbro. Scale 1 mile to the inch. The black bed at the base of the Animiké is the ferruginous horizon. The remainder of the Animiké in the section is composed of slates and slaty quartzites with interstratified greenstones.

the way in which the latter beds, to the north of the two lakes mentioned, fit into the sinuosities of outline of the older formation. The entire contrast as to lithological characters between the two sets of rocks furnishes further proof. A north

and south section midway in Gunflint Lake is given herewith to illustrate these relations. So far as it is developed along the national boundary line the lowest layers of the Animiké series in sight are those on Gunflint Lake. The highest layers are those in the vicinity of Grand Portage Bay, the whole succession between these points being some thousands of feet in thickness. The iron-bearing horizon at the base of this succession is lithologically identical with that of the Penokee series of northern Wisconsin and Michigan, while the black slates, greywackes, etc., which succeed the iron-bearing horizon are in turn the counterparts of those which form the middle and upper portions of the Penokee series. The interstratified gabbros of the Animiké are wanting, however, or are relatively rare in the Penokee region.

In attempting to trace the Animiké rocks from this area farther west than southwest we find ourselves constantly balked by the overlapping layers of the Keweenaw series. This overlap will be best appreciated on an inspection of the accompanying map, upon which it is shown that the basal olivine gabbros of the Keweenaw series entirely cut out the Animiké in its surface distribution, coming, a few miles to the northward of Gunflint Lake, directly into contact with the older schists. Continuing southwest nothing farther is seen of the flat-lying Animiké beds for over fifty miles, but in the vicinity of the south side of Birch Lake they emerge from beneath the overlapping gabbro. From here the lower members of the series, with the usual flat southeasterly dip, and with the lithological characters well-preserved, may be traced along the south side of the Mesabi granite range as far as the Embarrass Lakes, a distance of some twenty-five miles; in which distance they are plainly in unconformable abutment upon the granite to the north. After this they are concealed entirely, so far as present knowledge is concerned, by the immensely heavy drift-covering of the region, until the vicinity of Pokegama Falls on the Mississippi River is reached, some sixty miles farther to the southwest. Here the basal layer of the Animiké is a reddish quartzite followed by, and associated with, layers of cherty iron ores like the remaining ones of the Animiké series. These layers dip at the usual flat angle to the southeastward and rest unconformably upon gneiss and granite, which are plainly the direct continuation of those of the Mesabi range.

Southward and eastward of the line from the Mesabi range to Pokegama Falls the rocks are mainly concealed by swamp or heavy drift covering, but a great display of the upper portions of the Animiké series is seen again along the St. Louis River from Knife Falls to Thomson, where they are cleaved

and folded argillaceous slates. Farther south and west these slates may be traced into continuity with mica-schists, which, on the Mississippi River, in the vicinity of Little Falls, are staurolitic and garnetiferous. These upper horizons of the Animiké are the counterparts of the upper horizons of the iron-bearing series in the Penokee region and again in the Marquette region of Michigan.

The Animiké rocks of this region are thus conformably placed upon an older series of schists and granites, and lie unconformably beneath the newer Keweenaw series, the latter unconformity being indicated by the manner in which the basal beds of the Keweenaw series traverse the courses of those of the Animiké, and by the folded condition of the Animiké slates in the vicinity of the St. Louis River; the crumplings in this case having plainly preceded the accumulation of the Keweenawan beds.

Thus the Animiké series occupies very plainly the stratigraphical position of the original Huronian, and of the various iron-bearing groups of the south shore of Lake Superior. Since it is also intrinsically so extraordinarily like the Penokee series as to leave no doubt of their identity; and since the Penokee is as evidently the equivalent of the original Huronian, we seem to be left no choice as to calling the Animiké Huronian also.

[To be continued.]

ART. XXIX.—*Oxygen in the Sun; Contributions from the Physical Laboratory of Harvard University;* by JOHN TROWBRIDGE and C. C. HUTCHINS.

[From the Proceedings of the American Academy of Arts and Sciences, vol. xxiii; Investigations on Light and Heat, made and published wholly or in part with Appropriation from the Rumford Fund. Presented March 9, 1887.]

SINCE the time it was announced that hydrogen existed in great abundance in the sun's atmosphere and was a controlling element in its economy, there have been no more interesting questions in solar physics than those touching the presence of other gases in the sun's body and atmosphere; and when we consider the important part that oxygen plays in terrestrial affairs, the great variety of combinations into which it enters, and its high constituent percentage in the composition of the earth itself, a peculiar interest, second to that of no other element perhaps, attaches to its probable presence in the sun.

The investigation of the spectrum of oxygen as a research by itself, and as connected with its presence in the sun, has occupied many eminent physicists; but the fact that the latest

and most complete investigations have left the minds of scientific men still in doubt, has led the writers to take up the question again with more perfect and powerful apparatus and increased facilities, in order if possible to add something to the knowledge of the subject.

The question of the existence of oxygen in the sun was first seriously investigated, we believe, by Dr. Henry Draper, who published in the American Journal of Science for 1877 and 1879, and in foreign journals, papers accompanied by reproductions of his photographs. Dr. Draper was firmly persuaded of the existence of oxygen in the sun's atmosphere, and based this belief upon the apparent coincidence of the lines of oxygen taken in air with certain bright spaces in the sun's spectrum which appeared upon his photographs.

Prof. John Christopher Draper published a paper in the American Journal of Science for 1878, in which he stated his conviction that oxygen exists in the sun; but his line of argument was just the reverse of that of Dr. H. Draper. While the latter apparently proved the existence of oxygen in the sun by the coincidence of its bright lines with bright spaces in the solar spectrum, the former was led to believe that the bright oxygen lines coincided with dark lines in the sun.

Both observers abandoned the old method of eye observation, and took advantage of the improvements in photography to record the oxygen lines upon a sensitive plate. Dr. H. Draper was led to abandon Geisler's tubes filled with oxygen, and to employ the electric spark in common air, on account of the greater brilliancy of the lines, while Prof. J. C. Draper still adhered to tubes filled with rarefied oxygen. The oxygen lines had been mapped by previous observers, notably by Thalen, and Schuster had shown that there were four spectra of oxygen which could be produced under varying conditions of temperature and pressure.

The photographs of Dr. Henry Draper's oxygen spectrum, together with the juxtaposed solar spectrum, were submitted to the French Academy of Sciences in Paris, June 23, 1879, by M. Cornu. From the remarks of M. Faye we make the following extract:—

"Dr. H. Draper has, however, succeeded in discovering oxygen, not in the chromosphere, but in the photosphere, where it discloses itself by bright lines. It is obvious that this gas is dissociated at a depth, and is immediately taken up by multiple combinations in the region and at the temperature of the brilliant surface. I see in these facts the hope of a confirmation, and above all of an extension, of the views I have put forth on the constitution of the sun; but whatever may be the fate that the progress of spectrum analysis reserves to them,

I express here my admiration for the discovery of Mr. Draper, and I hope that his results, so well confirmed by the photographic proofs that our learned member, M. Cornu, has shown the Academy, will not delay in being universally accepted by competent judges."

The opinion thus expressed by so eminent an authority as M. Faye testifies to the strength of the evidence brought forward by Dr. Draper. With the exception of Prof. John C. Draper, physicists, in so far as they have expressed their views, have generally accepted the hypothesis of Dr. Draper. No one, to our knowledge, has critically examined the hypothesis of bright lines in the solar spectrum.

The reader of Dr. H. Draper's account of his experiments will remember the difficulties he encountered in obtaining an air spectrum, of sufficient brightness to record itself upon the photographic plate. The time that has elapsed since his work does not seem to have made those difficulties less, and, in spite of all that our ingenuity has been able to devise, we have been practically confined to taking the spark in free air or oxygen at atmospheric pressure, notwithstanding the broad and hazy character of the lines under these conditions.

Not to record a long list of failures extending over several months, we will briefly describe the arrangements in their final form.

An alternating current dynamo driven at 2,000 revolutions per minute is connected to a commutator of four segments upon a fixed spindle, around which revolve two pairs of brushes. The result of this combination is that the current is very frequently and sharply interrupted. This interrupted current is used to excite three large quantity coils connected in series. From two to twelve jars were employed as a condenser to the secondary current. The spark was taken between two stout rods of aluminium placed immediately in front of the slit, and the spark passed between them with a deafening rattle, and gave about the light of two candles. We tried Dr. Draper's device of a soapstone compressor for the spark, but in our hands the walls of the soapstone near the spark melted down, and formed a conducting surface over which the current passed.

The photographic apparatus is the large instrument of Professor Rowland,—a concave grating with ruled surface 6×2 inches, mounted upon an iron girder 23 feet long, moving upon two tracks at right angles, as has been previously described by him and others. Sunlight is introduced by a heliostat with mirror silvered on first surface, and an image of the sun formed on the slit by means of a quartz lens of five feet focus. The method of working with the apparatus so arranged has been as follows.

The points of aluminium being permanently fixed in front of the slit, sunlight is introduced, the camera brought to focus once for all, and set to any required wave-length upon a convenient scale. The photographic plate is then placed in the camera, and a shutter immediately in front is set to expose the upper half of the plate. Exposure for the sun is then made; the sunlight is then cut out, and the shutter moved to cover that part of the plate already exposed, and the lower half exposed. The spark is then started and worked from 15 to 30 minutes. In addition to the spectrum of lines there is a considerable continuous spectrum, which after a time causes fogging of the plates; so there does not seem to be any gain in an exposure of more than half an hour. The feebleness of the air lines can be judged of when we state that, with the same plate, breadth of slit, etc., we get a metallic spectrum in the arc in ten seconds, strongly photographed. There was sufficient iron present in the electrodes as impurity to give the strongest iron lines feebly, and these have been of use in determining that no displacement had happened, although from the nature of the arrangements such disturbance could hardly occur.

On the negative produced as above indicated the two spectra lie exactly edge to edge, like a vernier and scale, and are in the best possible position for the accurate determination of the position of the air lines. The original plan contemplated a determination of wave-lengths of all the air lines throughout the entire spectrum; but persistently bad weather and other causes have compelled the postponement of the completion of this work, though we are now able to give it complete from wave-length 3740 to wave-length 5030.

The photographic map of the solar spectrum of Professor Rowland has made easy what would otherwise have been an undertaking of extreme labor and difficulty. The best of engraved maps of the violet region of the spectrum to beyond F are comparatively worthless. Even on the elaborate map of Vogel, the result of years of labor, it is difficult certainly to recognize other than the more prominent lines, and you never feel quite sure of your positions; but we turn to the map of Rowland with the certainty of finding every line in its true order and magnitude, so that what was formerly most difficult has now become very simple, and the position of any well-defined air or metallic line can be read directly, by comparison of the photograph with the map, to the tenth of a wave length.

We here give a table of wave-lengths as determined from our photograph of the sun and air spectra:—

3749·80	Strong, agrees.
3755·35	" "
3830·60	Faint and broad.
3839·275	Dim and broad.
3842·30	Very faint.
3843·00	"
3850·70	Faint.
3857·40	"
3863·80	"
3864·90	"
3882·45	Strong.
3893·50	Faint.
3894·95	"
3896·40	"
3896·90	"
3900·975	Sharp.
3902·20	Very faint.
3906·00	Sharp.
3912·30	Fairly strong.
3919·25	Strong, agrees.
3935·10	Very faint.
3936·90	Faint.
3938·80	"
3939·80	"
3940·70	"
3941·40	"
3942·48	Sharp.
3946·20	"
3948·10	Very faint.
3949·00	Sharp, may agree.
3951·45	"
3954·85	Strong.
3956·175	Strong, agrees.
3958·10	Faint.
3958·90	
3959·975	Sharp.
3963·70	"
3968·70	
3973·60	Strong.
3981·40	
3982·97	Faint.
3992·87	Sharp, agrees.
3995·10	Very strong.
3998·81	Very faint, may agree.
4008·39	
4011·34	Faint.
4035·34	Band.
4041·39	Band.
4066·84	Faint.
4070·24	Strong, may agree.
4072·34	"
4076·19	"
4078·83	Faint, agrees.
4085·24	
4085·84	
4088·64	Faint.
4093·09	"
4097·49	"
4105·04	Strong.
4105·21	"
4109·76	Very strong.
4111·01	Very faint.
4112·16	"
4119·36	Fairly strong.
4120·46	Faint.
4121·52	"
4121·56	"
4123·82	Agrees.
4132·82	Faint.
4133·79	"
4145·87	
4147·42	
4151·92	
4153·57	May agree.
4155·42	Faint.
4156·79	
4164·72	Faint.
4166·72	"
4169·47	Agrees.
4172·12	
4175·72	Band.
4177·92	Very faint.
4179·92	Faint band.
4185·32	Very strong.
4190·00	"
4193·77	Very faint.
4198·72	
4199·22	May agree.
4202·12	"
4205·72	Very faint.
4206·92	Band.
4209·12	Very faint.
4214·92	"
4223·17	Faint on band.
4224·92	" "
4225·92	" "
4228·52	Band.
4236·67	"
4241·92	
4249·02	
4253·42	Very faint.
4266·32	Faint.
4271·22	"
4274·82	Very faint.
4277·90	Faint.
4279·90	Fairly strong.
4282·40	Faint.
4291·90	"
4303·80	Very faint.
4305·67	"
4309·87	Faint and sharp.
4312·72	" "
4315·52	" "
4317·20	Strong.
4319·50	"
4322·80	Faint, may agree.
4323·90	Very faint.
4325·90	Agrees.
4327·60	Very faint.
4328·42	"
4330·37	"
4331·20	"
4332·40	Sharp.
4336·77	
4345·52	Strong.
4347·47	Faint.
4347·94	Strong.
4349·30	"
4351·40	"
4353·70	"
4356·62	Faint.
4362·90	
4365·40	Faint.
4366·92	Strong.
4369·60	Faint.
4371·40	"
4379·70	"
4381·50	"
4385·30	Very faint.
4385·40	"
4386·50	Nebulous.
4396·30	Faint.
4401·22	
4415·00	Strong, agrees.
4417·17	" "
4421·00	Faint.
4426·00	"
4430·04	"
4431·90	Very broad dim band.
4434·27	Sharp.
4439·47	Broad dim band.
4443·00	" "
4447·09	Very strong.
4452·40	Sharp.
4456·00	Faint and sharp.
4459·90	Faint.
4465·40	Sharp.
4466·00	"
4468·02	Very faint.
4469·50	"
4472·90	"
4477·87	Broad and faint.
4481·87	Sharp.
4487·94	
4489·90	Faint
4496·97	Sharp.
4498·95	Faint.
4503·05	Fairly strong.
4507·72	"
4511·85	Sharp.
4520·50	Strong, may agree.
4544·50	Fairly strong.
4565·97	Sharp.
4572·02	Sharp, agrees.
4577·50	Sharp.
4578·55	"
4582·32	"

4583·15	Very strong.
4587·45	Sharp.
4588·05	"
4588·92	Very faint.
4589·40	"
4590·00	"
4590·95	Strong, may agree.
4592·00	
4592·95	Strong.
4596·20	"
4601·37	Very strong.
4607·20	"
4609.45	Sharp, may agree.
4612·75	Faint.
4614·05	Strong, agrees.
4621·42	Strong.
4630·73	Very strong.
4634·00	Sharp.
4638·90	Strong.
4640·75	Rather faint.
4641·90	Fairly strong.
4643·45	Strong.
4645·40	Faint.
4649·25	Strong.
4651·02	Fairly strong.
4654·10	Faint.
4654·85	"
4655·90	Faint band.
4658·05	Very faint.
4659·60	"
4665·70	Faint.
4667·55	"
4671·65	"
4672·30	"
4673·30	Very faint.
4674·95	Faint, may agree.
4676·40	Faint, may agree.
4681·10	Very faint.
4682·40	"
4687·15	"
4688·80	"
4691·40	"
4694·15	Strong.
4695·15	Faint.
4696·70	Very faint.
4699·40	Broad and faint.
4700·40	Faint.
4701·65	"
4703·02	Agrees.
4705·42	Fairly strong.
4710·20	"
4712·87	Very faint.
4719·92	"
4731·27	"
4733·95	"
4740·20	"
4744·20	"
4753·82	Sharp.
4760·07	"
4763·82	"
4771·82	"
4775·07	"
4782·62	Very strong.
4788·27	Very faint.
4791·32	Sharp, agrees.
4798·97	Very faint.
4800·82	"
4802·37	Very strong.
4808·94	Very faint.
4810·02	Faint.
4811·92	"
4813·52	"
4816·60	Very strong.
4820·90	Faint.
4822·12	Faint.
4825·12	Faint, may agree.
4842·00	Faint but sharp.
4863·92	" "
4877·70	Faint.
4878·80	Very faint.
4879·90	"
4891·27	"
4894·90	"
4898·70	"
4906·77	"
4907·67	"
4913·69	Sharp.
4915·12	Sharp, but faint.
4916·86	Sharp.
4936·86	Band.
4940·85	Sharp.
4945·01	"
4945·81	"
4950·21	"
4951·41	Nebulous band.
4953·85	Sharp, agrees.
4955·16	
4960·16	
4969·85	
4972·85	
4979·90	
4983·06	Sharp, may agree.
4993·95	Faint.
4997·60	"
4999·31	Agrees.
5001·55	Faint.
5011·06	Sharp, agrees.
5012·50	Faint.
5018·55	May agree.
5022·95	Faint, may agree.
5033 85	Very faint.

In regard to the accuracy that may be expected of the above positions, we feel sure that few of them are wrong by more than a tenth of a wave-length, and those are of the class "Very faint," or "Broad and nebulous." The better defined lines we believe to be correct to within less than the above amount. The method of comparison we have used admits of much greater accuracy than this, but the ill-defined character of the air lines puts a limit to their accurate placing. Compared with Thalen's positions, they should be credited with ten times the accuracy at least. Some of Thalen's bands are resolved into two or more in our instrument.

Prof. John C. Draper projected his spectra upon a scale of wave-lengths by means of a stereopticon,—a method which does not inspire confidence in his results, when we consider the distortion produced by projecting lenses.

The scientific world seems largely to have accepted the wave-lengths of Ångström and Thalen as final. One eminent au-

thority speaks of them as the "ne plus ultra" of spectroscopic accuracy; and any attempt to revise or correct them may be looked upon as presumptuous. However, we believe the time has arrived when the whole of Thalen's work on metallic spectra must be re-examined. It is safe to say that he has tabulated not more than one line in many metals where several exist, and his positions are occasionally wrong by as much as two wave-lengths.

As yet no approach to the accuracy with which the solar spectrum has been delineated has been attempted in metallic spectra,—a remarkable fact, when we consider that the chief interest that attaches to the study of the solar spectrum is in its connection with spectra of terrestrial elements.

The test of the existence of oxygen in the sun is the coincidence of the bright lines of the spectrum of oxygen with bright lines or with dark lines of the solar spectrum. If the bright lines of any metallic vapor formed in the electric arc or the electric spark coincide with the dark lines of the solar spectrum which is photographed directly above the spectrum of the metal on the same sensitive plate, the evidence is usually considered conclusive in regard to the existence of the metal in the sun. In the case of iron, where hundreds of lines of the metal coincide with the dark lines in the solar spectrum, not only in exact position but in general grouping and character, the evidence cannot be doubted by any one who has carefully examined it. When a majority of the lines of any metal coincide with dark lines in the solar spectrum under high dispersion, not only in position but in grouping, while a few of the metal lines have no representatives in the solar spectrum, there is a probability that the corresponding lines wanting in the sun have been obliterated by superposed lines or bands of other metals. In our paper "On the Existence of Carbon in the Sun," we have called attention to a case of such obliteration. It is probable, also, that the non-appearance of certain lines in the sun may be due to certain conditions of temperature. We have discussed this point more fully in the paper on carbon, above referred to.

The same remarks apply to the coincidence of the lines of any element with the supposed bright spaces in the sun. The value of the test of coincidence increases with the number of coincidences. If an element has only two or three lines, and these two or three agree in position with dark lines in the solar spectrum, the evidence of the existence of the element in the sun is not conclusive. It is supported, however, if there is any striking peculiarity in the lines of the element which is reproduced in the corresponding lines in the solar spectrum. Thus the nebulous character of the lines of magnesium is perfectly

reproduced in the corresponding lines in the solar spectrum. The test of coincidence, therefore, requires primarily a normal spectrum and the highest possible dispersion. The earlier observers were limited to the instruments of small dispersion, and the entire number of lines observed in the solar spectrum was small compared with that given by the best modern apparatus. The chances for an apparent coincidence were therefore much greater, and evidence of a very misleading character could be obtained.

In Dr. H. Draper's published photograph, the coincidence of the greater part of the oxygen lines with bright bands in the solar spectrum is striking; and it is not a matter of surprise that he was led to conclude the connection between the two spectra to be a physical one, and to announce the existence of oxygen in the sun as proved. Instances are not infrequent where instrumental imperfection or lack of power has led to results unsupported by later and more powerful research. Witness the spots of Venus of the older observers. Now when we apply to the spectra of the sun and oxygen a dispersion and definition that show the minute detail of each, the "bright bands" at once vanish, or no longer appear as such, and all the apparent connections between them and the oxygen lines disappears also. The bright bands of Dr. H. Draper's spectrum are found to be occupied by numerous dark lines, of various degrees of intensity; but the hypothesis of Prof. J. C. Draper, that these are the true representatives of the oxygen lines, is rendered untenable by the lack of any systematic connection between the two. It happens quite frequently that an oxygen line falls centrally upon the space between two dark lines of the solar spectrum, but not more frequently than we might expect as a matter of chance, when we consider the vast number of lines and spaces; and the fact that the spaces are no brighter than the surrounding background of the solar spectrum would not seem to permit of their interpretation as bright lines.

The subject of bright lines in the solar spectrum is one upon which men will probably differ, and we have sought information upon it. Of course there is no *a priori* reason why such bright lines should not exist, as they do in many stars; but we have photographed the sun's spectrum every day that the sun has shone for nearly five months, without finding a line that could with certainty be pronounced brighter than its neighbors; and it must be admitted that the photograph is the best of photometers in such a case.

In regard to the other three spectra of oxygen of Schuster we have nothing to say; but as far as concerns the spark spectrum in air and the solar spectrum from wave-lengths 3749·8 to 5033·85 we can safely affirm that there is no physical connection between them.

ART. XXX.—*Bismutosphærite from Willimantic and Portland, Conn.;* by H. L. WELLS.

THROUGH the kindness of Professor Brush I have been enabled to examine two specimens of basic bismuth carbonate which are of considerable interest, inasmuch as their composition appears to be identical with that of Weisbach's bismutosphærite.* Weisbach gave this name, upon reinvestigation, to Werner's "Arsenik-Wismuth," which, as he remarks, had been called "Luftsaures Wismuth" by Adolph Beyer, who died as early as 1805. The composition of bismutosphærite has been considered doubtful† because Winkler's analysis included no water and footed up only to 97·83 per cent, but Weisbach states distinctly that the mineral is anhydrous, and, since Winkler used only 330 milligrams of the material for his analysis, it is quite probable that his loss may have been due to other causes than the presence of water.

The specimen from Willimantic, which weighed about ¼ lb., was given to Professor Brush by H. N. Bill, Esq., of Willimantic, who has kindly furnished the following description of the locality. "The mineral occurs in small isolated masses embedded in albite with garnets. The vein of which it was a part was composed of large crystals of orthoclase, muscovite and occasional fine crystals of smoky quartz. The locality is on the Linen Co's property near the west end of mill No. 2. A considerable outcrop of gneiss originally existed at this point, but it has all been utilized in building the mill. It was during the blasting of this ledge that the vein was opened and the mineral discovered. The locality is now inaccessible, the blasted portion being covered by a fine grassy lawn, while the portion originally exposed in the bed of the river has been flooded by a pond."

The material of which the specimen is almost wholly composed has a dark gray color and gives a light gray streak. It shows evidences of a bent columnar structure, suggesting that it is a decomposition product of bismuthinite, and a small nucleus of bismuthinite, found in the interior of the specimen by Professor Brush, shows that this is the actual source of the mineral.‡ Its hardness is between that of calcite and that of fluorite (3·5). The specific gravity is 7·42 according to a determination made on a chemical balance with the precaution of removing air from the fragment used by placing it in boiling water before

* Jahrb. Berg-Hütten., 1877, p. 49.—Dana's Mineralogy, 5th edition, Appendix III, p. 15.

† A. H. Chester, this Journal, III, xxxiii, p. 291.

‡ Weisbach states (l. c.) that the original bismutosphærite often encloses a nucleus of metallic bismuth.

the weight in water was taken. Heated in the closed tube it gives off a minute quantity of water and melts readily. It dissolves in acids with effervescence; with HCl a small, flocculent, black residue is left in which bismuth and sulphur were detected; with HNO_3 it dissolves completely. Scattered through the gray material numerous minute shining scales are to be noticed, which are most numerous along the cracks or more easily separated surfaces. A small cavity in the specimen was lined with these scaly crystals. They have a white color with a brilliant luster. Their aspect is orthorhombic, but they are too small and thin for measurement. Qualitative tests showed that they are composed of an anhydrous bismuth carbonate, and it seems probable that their composition is identical with that of the massive material in which they occur, but, unfortunately, there was not enough of the crystals which could be separated from the gray material to afford material for a quantitative analysis.

On some parts of the specimen a yellowish-white coating is to be observed, which in places is made up of minute spherical nodules, the form on a small scale of the original bismutosphærite.* This is also apparently an anhydrous bismuth carbonate, but, like the scaly crystals, its quantity is too small for quantitative examination.

Mr. S. L. Penfield has kindly made an optical examination of the gray substance and reports as follows: "A thin section does not at first sight appear to be homogeneous, but shows under the microscope a dark ground-mass through which irregular patches of a pale yellowish-green color are scattered. The light patches are not perfectly transparent, but are translucent and have the appearance of a kaolinized feldspar. The material of the darker ground-mass is probably the same as that of the light, but stained and rendered practically opaque by fine particles of dust of some black material. If, as is probable, the mineral is a decomposition product, the black dust-like particles may be the last traces of the original mineral. Light streaks, which may be original cleavage directions along which decomposition has gone on more completely, indicate crystalline structure, while the lighter, translucent parts of the section polarize the light and show an extinction parallel to these directions."

A chemical examination gave much more satisfactory results in regard to the purity and homogeneity of the mineral than would have been expected from the results of Mr. Penfield's microscopic examination. The actual amount of the black material, probably bismuthinite in an extremely fine state of division, which had such a marked influence upon the transparency of the thin section, proved to be very small; moreover, a careful qualitative analysis showed that the only impurities besides the

* In this a size larger than that of a pea is mentioned by Weisbach.

bismuthinite are a trace of iron and in some parts a very small quantity of insoluble silicates. The remarkable uniformity in the composition of separate portions, as shown by the analyses which follow, is a strong argument in favor of homogeneity.

Mr. E. S. Sperry of this laboratory has made the following analyses of two separate portions.

	A.	B.		
		I.	II.	III.
Bi_2O_3 by ignition,	92·07	92·05	92·04	92·07
CO_2	8·01	7·90	7·96	7·91
H_2O	0·90	0·48	0·66	0·49
	100·98	100·43	100·66	100·47
Bi_2O_3 by determination as BiOCl	----	----	----	91·09

The above analyses and those that follow were made by igniting the substance in a boat in a combustion-tube through which dry air was passed. More than 1 gram of substance was used for each analysis. The H_2O and CO_2 were collected and weighed as in organic analysis, while the residue in the boat gave the "Bi_2O_3 by ignition." In one case, B III, this residue was dissolved and BiOCl was weighed on a Gooch filter. In these analyses the small amount of Bi_2S_3 present was disregarded, but Mr. Sperry made a determination of the residue insoluble in dilute HCl by collecting it on a Gooch filter, drying at 100° and weighing. He found:

	B. IV.
Black residue	0·56 per cent.

Mr. Sperry's analyses showed such uniformity in the two portions examined that I was led to make a somewhat more detailed analysis of a third sample. My results were as follows:

	C. I.		Calculated for Bi_2CO_5
Bi_2O_3	91·64*		91·41
SO_3	0·34	92·06 ignited residue.	
Insoluble silicates	0·08		
Fe_2O_3	trace		
CO_2	8·03		8·59
H_2O	0·47		
	100·56		100·00
Deduct O,†	·28		
	100·28		

* By difference; i. e., the ignited residue minus the SO_3 and insoluble silicates.

† It is assumed that the SO_3 contained in the ignited residue resulted from the oxidation of Bi_2S_3; therefore 4 atoms of oxygen are deducted for each atom of sulphur.

	C. II.
Black residue insoluble in HCl,	0·49 per cent.
Deduct insoluble silicates,	0·08
Bi_2S_3 by difference,	0·41

The result obtained from the analysis of the Willimantic mineral led me to examine a specimen of bismuth carbonate in Professor Brush's collection from Pelton's quarry, Portland, Conn. This specimen has a greenish-yellow color, and gives reactions like the specimen from Willimantic, except that it does not leave a black residue when dissolved in HCl. It shows evidences of a bent columnar structure, but on a much smaller scale than the other specimen. Under the microscope it appears as a somewhat porous mass, made up almost wholly of an apparently homogeneous material of a yellowish green color with an oily luster, but with some streaks of different colored material varying from white to dark gray. A specific gravity determination gave the number 6·83, but this is of little value on account of the porosity of the mineral. Chemical analysis gave the following results:

Ignited residue,	91·82
CO_2	7·54
H_2O	0·94
	100·30

A determination of Bi_2O_3 in the "ignited residue" gave 89·03 per cent. The difference, amounting to 2·79 per cent, between the Bi_2O_3 determined and the "ignited residue" is probably to be accounted for by the presence of 0·49 per cent of insoluble silicates, and also a little CuO and a considerable amount of Fe_2O_3 which were not determined.

The analyses given in this article were all made on the air-dry material; drying, even in the desiccator, having been avoided from fear of removing water which belonged to the composition of the mineral. From the small amount of water found, since a part of it was probably hygroscopic moisture, and, since weighing water in a calcium chloride tube is apt to give slightly high results, these two specimens of bismuth carbonate must be regarded as virtually anhydrous; and, since the analyses agree quite closely with the composition corresponding to the formula $Bi_2O_3 . CO_2$, the existence of bismutosphærite must be considered as established, although the name is not appropriate to the external form of the specimens under consideration, unless, indeed, the slight coating on that from Willimantic shows on a small scale the form from which the mineral is named.

Sheffield Laboratory, May 18, 1887.

ART. XXXI.—*Note on some remarkable Crystals of Pyroxene from Orange County, N. Y.;* by GEORGE H. WILLIAMS.

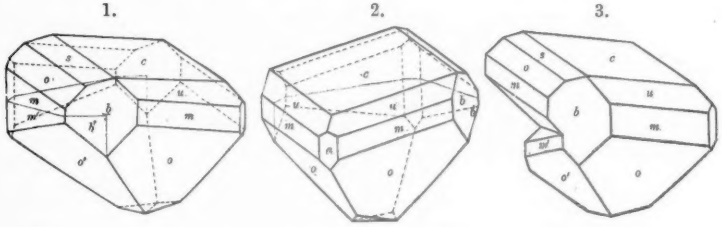
CERTAIN yellowish gray crystals of pyroxene occurring in the crystalline limestone of Orange County, N. Y., have a very peculiar tabular habit produced by the unusual development of the basal pinacoid. Dr. Lewis Beck figures these crystals in his Mineralogy of New York,* although his drawing wrongly represents the basal plane in the position of the orthopinacoid, for which he evidently mistook it. Beck gives the locality for these crystals as two and a half miles north of Edenville. In 1860, Professor G. vom Rath described and figured some of the same crystals from the collection of Dr. Krantz in Bonn.† He gives the locality where they are found as Warwick, Orange County, N. Y., which is probably less accurate than that given by Beck. Vom Rath's first figure represents a crystal of the ordinary habit; tabular according to the base (*c*) and showing besides the forms: $\infty P \overline{\infty}$ (*a*), $\infty P \breve{\infty}$ (*b*), ∞P (*m*), P (*s*), 2P (*o*) and $-P$ (*u*). His second figure represents a twin crystal of a more prismatic habit, formed according to the common law for pyroxene. This shows, in addition to the above named planes, the form $P \overline{\infty}$ (*p*). Vom Rath further mentions the striation of these crystals parallel to their basal pinacoid, which he refers to an irregularity of growth, although he was the first subsequently to explain it as due to twinning.‡ He also says that they are externally changed by paramorphism to an aggregate of fine hornblende needles, which produces a lustrous shimmer on the surfaces.

Professor Des Cloizeaux also mentions and figures these crystals in the first volume of his "Mineralogy" published in 1862.§ His first figure is like vom Rath's and represents a similar simple crystal. His second shows a hemimorphic development in the direction of vertical axis, there being on one side of the prismatic zone the forms: 0P (*p*), P (*s*), 2P (*o*), $P \breve{\infty}$ (*e*), and $-2P2$ (*μ*); and on the other side: 0P (*p*), $-P$ (*u*) and $-\frac{3}{2}P3$(*a*) No mention of twin crystals from this locality (given as Warwick) is made by Des Cloizeaux.

A remarkably fine group of these Orange County pyroxene crystals, which came into the possession of the Johns Hopkins University mineral cabinet with the purchase of the collection of the late E. W. Root of Clinton, N. Y., seems worthy of a brief notice on account of the singularity of their form. This

* Mineralogy of New York. Albany, 1842. 4°, p. 293, fig. 215.
† Pogg. Ann., Bd. cxi, p. 263, taf. iii, figs. 5 and 6.
‡ Zeitschrift für Krystallographie, v, p. 495, 1881.
§ Manuel de Minéralogie, vol. i, p. 54, 1862. Atlas, figs. 57 and 58.

group consists of six simple crystals of the usual tabular habit and of two larger ones, which are at the same time twins and hemimorphic. The largest of these crystals measures $3 \times 3\frac{1}{2}^{cm}$, and is represented in figures 1 and 2. The upper portion



belongs to a single individual, having the usual habit and showing the usual forms: 0P (*c*), −P (*u*), P (*s*), 2P (*o*), ∞P (*m*), ∞P$\bar{\infty}$ (*b*) and ∞P$\bar{\infty}$ (*a*). Below, however, toward the front, we have only the forms: 2P (*o*) and P$\bar{\infty}$ (*p*), indicating that the crystal is hemimorphic in the direction of the vertical axis, as first noticed by Des Cloizeaux.* The lower back quarter of the crystal is moreover exactly like the lower front quarter, but in a reversed position, so that the lower half of the individual is a twin as represented by vom Rath, while the upper half is apparently simple and of the usual habit! The boundary of the quarter in twinning position is represented in the figure by the light line.

The second, slightly smaller crystal ($2 \times 2\frac{1}{2}^{cm}$) is essentially the same as the one just described, though it shows the twinning structure even more plainly, as may be seen from figure 3.

In all of these crystals the superficial alteration to hornblende has progressed so far as to render the planes unfit for exact measurements. The angles were, however, determined by a contact goniometer with sufficient accuracy to identify the symbols above given. The striation parallel to the basal pinacoid, so common in all pyroxene crystals from the crystalline limestones of New York, is here very distinctly marked.

Petrographical Laboratory, Johns Hopkins University,
Baltimore, Md., April, 1887.

* It is perhaps doubtful whether a crystal can properly be spoken of as hemimorphic in any direction except that of an axis of symmetry (cf. Groth), but this case is so analogous that it is difficult to describe it by any other term.

Art. XXXII.—*The Flow of Solids:* or Liquefaction by Pressure;* by William Hallock.

The question before us is this: Can solids be liquefied by pressure alone, without a rise of temperature? Also, is chemical action possible during this enforced liquid state? Applied to rocks and rock-making magmas it becomes a question of the first importance to geologists; as such it has been frequently discussed theoretically, but has seldom been experimentally investigated.

Walter Spring seems to be the pioneer in these tests, having published very many results during the past few years.† His memoirs† would seem to have proved beyond doubt that pressures under 7000 atmospheres will liquefy most solids,‡ and that it is only a question of slightly higher pressure to liquefy nearly all. He also finds that chemical action takes place under these circumstances,† at least where the volume of the product is less than that of the original materials. Unfortunately, or fortunately, our confidence in Mr. Spring's conclusions is seriously shaken by the criticisms of Ch. Friedel§ and Ed. Jannettaz,‖ who were not able to reproduce the results given. Henri Tresca¶ carried out many striking experiments upon the *flow* of solids, but did not touch the question of their liquefaction.

In order that I may not be misunderstood, I wish, as far as I am concerned, to give definite meanings to certain terms. Primarily I wish to distinguish sharply between causing a body to flow, and making it a true liquid. Any substance may flow when the forces acting to cause the molecules to change their relative positions is greater than that tending to hold them in their original positions; that is, greater than the rigidity of the substance. Two causes may then produce a flowing, an increase of the disturbing force, or a diminution of the resisting power, the rigidity of the material. Pressure may act as the first of these causes, and heat, the second.

* This is an abstract of a paper in the Bulletin of the Geological Survey, Chemical Division, for 1886–7, which is itself compiled from a report made September 9th, 1885, to the director, J. W. Powell, under whose direction I undertook this work, and by whose kind permission this abstract is published.

† W. Spring. Bull. de l'Acad. R. de Belg., II, xlix, 1880, and III, ix, 1885; and Bull. de la Soc. Chem. de Paris, xxxix, 1883, and xlvi, 1886.

‡ W. Spring. Bull. de l'Acad. roy. de Belg., II, xlix, 1880.

§ Ch. Friedel. Bull. de la Soc. Chem. de Paris, xxxix, 1883.

‖ Ed. Jannettaz. Bull. de la Soc. Chem. de Paris, xl, 1884. Bull. de la Soc. Mineral. de France, viii, 1885.

¶ Henri Tresca. Mem. de l'Inst. Savantes Etranges, xviii, 1868. Comptes Rendus, lxvi, 1868; lxviii, 1869.

Whether rupture or flow takes place in any given case, when the deforming overcomes the resisting force, depends upon the nature of the substance, its limiting conditions, and *the time allowed for the accomplishment of the motion.*

For convenience I would classify substances as: True solids, viscous solids, viscous liquids and true liquids. True solids retain their shape under ordinary circumstances indefinitely. Viscous solids gradually yield to gravity and flatten out. Viscous liquids "fill" their containing vessels only after a fraction of a second. True liquids fill their containing vessel practically immediately. Examples of each class are steel, lead or paraffine, tar and water, respectively. It goes without saying that we have no examples of *absolute* or *perfect* liquids or solids. Absolute rigidity is as unknown as absolute liquidity. If these ideas are correct true "liquefaction" is a diminution of the rigidity of a substance until its molecules change their relative positions as easily as in the "true liquid" above defined.

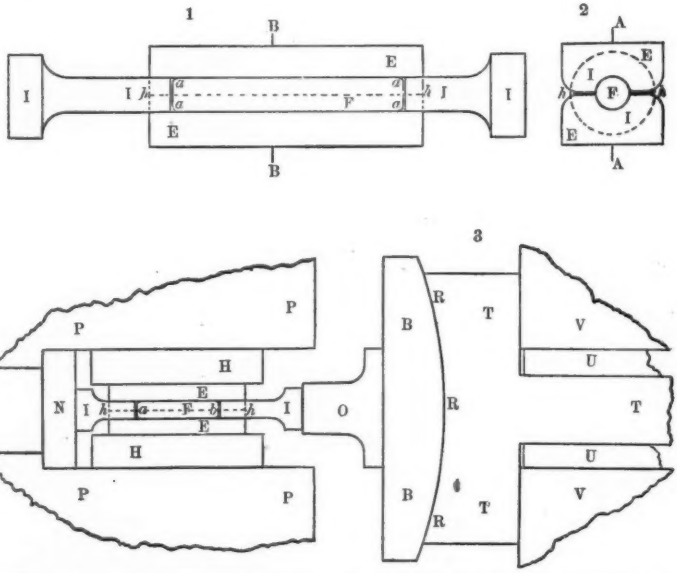
In order that a substance may undergo a change in its chemical or crystalline character, it would seem necessary that it should be in the condition, at least, of a viscous solid, in order that the molecules may rearrange themselves if there be any force urging them thereto. *A priori* it is inconceivable to me how or why pressure should impart this freedom to the molecules. With the exception of a few substances at isolated points, as water between 4° C. and ice at 0° C., an increase of liquidity, or a diminution of rigidity is simultaneous with an increase of volume, i. e., with the increase of the intermolecular distances, which is usually accomplished by heating the substance. *In general for one and the same substance over considerable ranges of condition, the rigidity diminishes as the intermolecular distances increase.* How can pressing the molecules nearer together be expected to give to them a property which always accompanies their separation?

Apparatus.—Through the kindness of the Chief of Ordnance we were permitted to use in its leisure moments the beautiful testing machine built for that department by A. H. Emery,* and situated at the U. S. Arsenal, Watertown, Mass. I also gladly acknowledge my debt of gratitude for kindnesses and many good suggestions to Col. F. H. Parker and Capt. John Pitman of the Ordnance Corps, and to Mr. J. E. Howard, the engineer in charge of the machine.

Fig. 2 shows a vertical section across the holder on the plane B B of fig. 1, which gives a vertical section on A A of fig. 2. E E are the two halves in contact at *h h*, enclosing the cylindrical hole F, in which the substance to be pressed is placed.

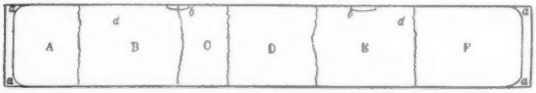
* Report of the Board on Testing Iron, Steel and other Metals, vol. ii, 1881. Government Printing office.

h h are strips of tissue paper used as packing between the two halves. I I, fig. 1, are the two pins acting as pistons fitting into the hole F, transmitting the pressure. *a a* are copper "gas checks" placed in front of the pins to flare out and fill tightly the hole F, preventing any escape of material. Figs. 1 and 2 are $\frac{1}{3}$ natural size, the hole was 1 inch in diameter. Fig. 3 (scale $\frac{1}{10}$) shows the manner in which the apparatus was held in the testing machine, and the pressure applied. P and P are the jaws of the hydraulic clamps of the machine (capacity 1,000,000 lbs). H H blocks of steel. N also a steel block, holds the back (left hand, stationary) pin in place. V V is the clamp of the fixed end of the machine where the pressure is weighed. To apply the pressure the clamp P P is forced toward V V by a hydraulic piston, thus forcing the holder E E over the pin resting against O. In this manner a total compressive force of 1,000,000 lbs. is available, carefully and delicately weighed by the hydraulic balance of the machine. The pins yielded at 110,000 lbs. per square inch, hence in the experiments only 96,000 lbs. per square inch or 6,400 atmospheres was used.



Experiments. — The amount of work done was computed from the load and compression, which showed that the possible heat generated would disperse into the holder and produce only an extreme rise of a few degrees centigrade.

"Granulated c. p. lead" in a paper roll was subjected to 6,000 atmospheres in the above apparatus. On taking it out there was not the least sign of fusion or true liquefaction. It was merely pressed together, and could easily be broken and reduced to the original grains between the thumb and finger. It is true these experiments were not performed *in vacuo*, a condition which Mr. Spring considers important. But if there is a true liquefaction, why does not the air rise to the top of the cavity and allow fusion as it does when the granulated lead is heated. There was no liquefaction—only a pressing or sticking together. Powdered bismuth behaved in precisely the same manner; also powdered calcite. As a critical experiment and a type of many others, the following may close those here enumerated.



The charge was composed as follows:

A, small section of antimony from a previous test.
B, piece of beeswax whittled round nearly filling the hole.
C, " " paraffine " " " " " "
D, ground bismuth in paper roll.
E, paraffine same as C.
F, small section of lead from a previous test.

d d, two double pointed tacks stuck radially into the wax and parafine; at *b b* two silver coins (old 3c. pieces) were laid on top of the wax and paraffine in the cylinder.

What is the condition of affairs to be expected after submitting this charge to 6,000 atmospheres? According to Mr. Spring's results we should expect the silver pieces and tacks to sink through the liquefied wax and paraffine, which would mix where in contact (B and C). Still more, the lead even would yield, then the antimony and bismuth, and these, by the action of gravity, would flow down and mix at the bottom of the cylinder while the wax and paraffine filled the top.

The actual result was that the substances *all came out just as they went in.* There was not the slightest trace of even a tendency to flow on the part of the metals. There was no sign of fusion between the wax and paraffine, which separated on their surface of contact (between B and C) clean and distinct. *d d* and *b b* did not sink to the bottom, but retained their original positions, the silver pieces were forced against the *top* of the cylinder so powerfully that their impression was left in the *steel* holder, easily seen and *felt*. The silver pieces were bent curved, fitting the inside of the cylinder. The wax and paraffine had yielded at first as viscous solids till they filled the cylinder, but under pressure developed a considerable rigidity.

It may be interesting here to quote some of Mr. Spring's results as obtained *in vacuo*.*

Lead—Perfect fusion at 2,000 atm.; at 5,000 atm. it ran, as a liquid, out of all the cracks of the apparatus.
Bismuth—6,000 atm. perfect fusion.
Tin—4,000 atm. fusion.
Zinc—5,000 atm. perfect fusion.
Antimony—5,000 atm. beginning of fusion.
Sulphur prismatic—5,000 atm. fusion to the octahedral form.
" plastic—6,000 " ditto.
" octahedral—3,000 " ditto.
and so on through a long and varied list.

Conclusion.—At this stage of the investigation it may be premature to speak of conclusions, but I think there are here at least a few straws which suggest in which direction we are to look. To me it seems established that pressure alone cannot truly liquify a solid, i. e. diminish its rigidity, consequently we should scarcely expect chemical or mineralogical changes to be produced by pressure alone. Solids, and very rigid ones too, can be made to flow and act in that respect as viscous liquids by pressure alone, but it overcomes their rigidity without diminishing it.

Future investigation may contradict or modify this conclusion; at present I believe it the only logical one to be drawn from the facts at our disposal.†

Art. XXXIII.—*Analyses of some Natural Borates and Borosilicates;* by J. Edward Whitfield.

In most of the published analyses of natural borates, boric acid has been determined either by difference or by some of the methods which have been shown to be inaccurate, and they are, therefore, subject to question as to the exact ratios and formulæ. A method for the direct estimation of boric acid‡ having been devised in this laboratory by Dr. F. A. Gooch it was thought advisable to repeat the analyses of a few of the borates and verify, if possible, the given formulæ or correct errors caused by defective analytical methods. With this object in view the following analyses were undertaken. The methods employed differ in many cases from those used by the analysts in the already published accounts of these minerals. In the estimation of the ferrous iron the method employed was to decompose the finely ground mineral with hydrofluoric and

* W. Spring. Bull. de l'Acad. R. de Belg., II, xlix. 1880.

† Since writing the above I have seen the article of E. H. Amagat [Comptes Rendus, July, 1887, this Journal, September, 1887] giving an account of his successful endeavors to do the opposite of what Mr. Spring did. He actually solidified liquid C_2Cl_4 by pressure alone.

‡ Am. Chem. Jour., ix, 23.

hydrochloric acids, in an atmosphere of carbonic acid, heating to a temperature of about 100° C. in a tightly sealed platinum vessel, devised and used expressly for such determinations. When the mineral was thoroughly decomposed, which is generally the case after standing twelve hours with occasional shaking, the solution was titrated with permanganate of potassium. This method is undoubtedly superior to that employed by Rammelsberg and Tschermak in their analyses. The direct estimation of the water was made, after drying the mineral at 104° C., with the apparatus devised by Dr. Gooch,* by which the errors caused by calculating the water from ignition and oxidation of the ferrous iron are eliminated. The silica in every case has been corrected by evaporation with hydrofluoric and sulphuric acids and the residue added to the precipitate of iron and alumina.

COLEMANITE, from Death Valley, California.—Of this mineral, there were put at my disposal two specimens very different in appearance. One of them, designated as A, was a large, transparent crystal of the ordinary type, to all appearances perfectly clear and free from impurities.

By analysis the following results were obtained, and I insert for comparison the analysis by Mr. J. T. Evans† and the theoretical composition calculated from the formula given below:

	A.	J. T. Evans.	Theory.
H_2O	21·87	21·835	21·9
B_2O_3	50·70	50·990	50·9
CaO	27·31	27·175	27·2
MgO	·10	----	----
	99·98	100·000	100·0

The molecular ratios from analysis A are $CaO : B_2O_3 : H_2O$—2 : 3 : 5—resulting in the simple formula $2CaO . 3B_2O_3 . 5H_2O$, the calculated composition of which does not differ much from the results of the analysis. Mr. Evans calculated the same formula from his analysis in which the boric acid was determined by difference.

The second specimen, B, was from the same locality, but was in the form of a deposit implanted on gangue, and consisted of small blade-like crystals, almost white, but in some lights appearing of a greenish cast. Two analyses yielded the following result:

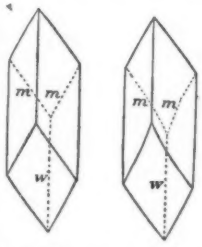
	B.	
	1.	2.
H_2O	22·66	22·70
B_2O_3	49·56	49·62
CaO	27·36	27·40
MgO	·25	·26
SiO_2	·44	·47
	100·27	100·45

* Am. Chem. Jour., ii, 247, 1880.

† Proc. Cal. Acad. Sci., No. 1.

These results prove the mineral to be the same as variety A, but containing very slight impurities. The difference in general appearance of the two specimens suggested a crystallographic examination of variety B, and the following description has been furnished by Mr. H. S. Washington of New Haven.

"The white transparent crystals, of about 2 to 5^{mm} in length, occur implanted on a light porous gangue either in parallel position or in rosette-like aggregations, overlapping one another like shingles on a roof. They have in several places implanted on them small, white, opaque, spheroidal masses. The habit of the crystals is remarkable, being unlike almost all the forms of colemanite previously described. Prof. A. W. Jackson* gives one figure resembling these forms, though more complex. They look, at first sight, like acute rhombohedrons of calcite; the combination of prism and orthodome giving the mineral a decidedly rhombohedral aspect, as is shown in the figure. None of the crystals examined admitted of good measurement, the faces being broken, rough, or curved. They were accurate enough however, for determining the symbols. The plane W was ($\bar{3}01$) curved very conspicuously and regularly, the face having near *a* (100) the position approximately represented by the symbol $\bar{5}01$. This habit was very constant, the prism *m*, (110) and orthodome W ($\bar{3}01$) being the only planes observed, with the exception of *b* (010) produced by the perfect cleavage, and a small and very uncertain plane observed in one or two cases replacing the edge between W ($\bar{3}01$) and *m'* ($\bar{1}10$)."



PRICEITE from Curry Co., Oregon.—The specimen examined was white and chalky, and proved to be very pure material; an analysis gave the following composition, and I copy the results of an analysis by Silliman† and another by Mr. Thomas Price‡ for comparison.

		Silliman.	Price.
H_2O	19·42	18·29	22·75
B_2O_3	48·44	[49·00]	[47·04]
CaO	32·15	31·83	29·96
$NaCl$, Fe_2O_3, Al_2O_3		·96	·25
	100·01	100.08	100·00

The ratios from my figures are $CaO : B_2O_3 : H_2O$—19 : 23 : 36, which do not conform to any simple formula. In both the earlier analyses the boric acid was determined by difference and there is a discrepancy between them of about 2 per cent.

* Bull. Cal. Acad., No. 4.

† Am. Jour. Sci., III, vi, 128.

‡ Am. Jour. Sci., v, 287.

PANDERMITE, from the island Panderma in the Black Sea.—The material was hard and compact somewhat resembling marble

H_2O	19·40
B_2O_3	48·63
CaO	32·16
	100·19

From these figures it will be seen that the priceite and pandermite are, in composition, identical, the difference being wholly in the physical appearance of the material, priceite is soft and friable while the pandermite is compact. From the results obtained there is no doubt but that they are the same mineral.*

ULEXITE from Rhode's Marsh, Esmeralda Co., Nevada.—The material for analysis was taken from one of the nodules found in this locality, which on being broken exposed the fine, silky fibers characteristic of the mineral. An analysis gave the following figures.

		Calculated composition.
SiO_2	0·04	
Cl	2·38	
B_2O_3	43·20	45·34
SO_3	0.28	
CaO	14·52	15·04
Na_2O	10·20	8·83
K_2O	0·44	
H_2O	29·46	30·79
	100·52	100·00
Deduct O for Cl	·53	
	99·99	

The molecular ratios from these figures are $Na_2O : CaO : B_2O_3 : H_2O$—16 : 26 : 62 : 163, which conform to no simple formula. If, however, we correct the analysis for impurities by throwing out the SiO_2, the K_2O as KCl, the remaining Cl as $NaCl$ and the SO_3 as gypsum ($CaSO_4 . 2H_2O$) we can calculate the composition given above, from which we deduce the formula $NaCaB_5O_9 . 6H_2O$, which lies between the two formulas given by Rammelsberg.†

LUDWIGITE, from Morawitza, Banat, Hungary.—The material consisted of fine, radiating, silky fiber, almost perfectly black, but showing a tinge of violet when freshly broken, very tough when hammered, but easily cut, associated with quite pure magnetite. Analysis gave:

* Dana's Syst. Min., App. III, 97. † Pogg. Ann., xcvii, 301.

B_2O_3	12·04
Fe_2O_3	37·93
FeO	15·78
MgO	30·57
MnO	0·16
H_2O	3·62
	100·10

The ratios are $B_2O_3 : Fe_2O_3 : FeO : MgO : H_2O = 17 : 24 : 24 : 76 : 20$; taking all the protoxides together with the water as basic, we have $B_2O_3 : Fe_2O_3 : RO = 3 : 4 : 20$. G. Tschermak* obtained for boric acid, by Marignac's and by Stromeyer's method, 16·09 per cent and 15·06 per cent respectively, but gives no water, and from his results deduces the formula $3MgO . B_2O_3 + FeO . Fe_2O_3$. If he sought for water by ignition, the oxidation of ferrous iron might easily have led to error.

DATOLITE.—The material investigated was the well known mineral from Bergen Hill, N. J., and consisted of crystals about 5mm in diameter, translucent, white or of a pale greenish color. I have been unable to find any published analysis of the mineral from this locality, although it has been known for so long a time. By analysis I obtained:

SiO_2	35·74
FeO	·31
CaO	35·14
B_2O_3	22·60
H_2O	6·14
	99·93

The small amount of iron is undoubtedly present as an impurity; leaving this out, the molecular ratios are $SiO_2 : CaO : B_2O_3 : H_2O = 60 : 63 : 32 : 34$, giving the formula $B_2O_3 . H_2O . 2CaO . 2SiO_2$, or $H . CaSiO_3 . BO_2$.

DANBURITE, from Russell, St. Lawrence Co., N. Y.—This mineral has been fully described by Professors Brush and Dana,† although from the description given by them of the color of their specimen, I imagine they had material differing somewhat from mine. The mineral analyzed was reddish yellow to pink in color, brilliant in luster and associated with pyroxene, quartz and calcite. In the analysis referred to‡ the boric acid was determined by Stromeyer's method. The figures obtained by my analysis are given in the first column, the second is the analysis made by Mr. W. J. Comstock for Professor Brush.

* Tsch. Min. Mitth., 1874, p. 59.

† Amer. Jour. Sci., III, xx, 111, 1880.

‡ Loc. cit.

	1.	2.
SiO_2	49·70	48·23
B_2O_3	25·80	26·93
CaO	23·26	23·24
$Fe_2O_3 + Al_2O_3$	1·02	·47
Ign.	·20	·63
	99·98	99·50

The comparison of the two analyses shows the material difference to be in the amount of impurities.

AXINITE.—Two specimens of this mineral from different localities were analyzed. The first, from Cornwall, England, was of selected crystals of a dark, clove brown color, translucent and implanted on quartz. The second was the axinite from Bourg d'Oisans, Dauphiny, France. This specimen was of a beautiful pearl-gray color, and in some of the smaller crystals almost colorless and quite transparent. The third analysis in the series is one of the Dauphiny axinite by Rammelsberg, and is copied from his description of the mineral* for comparison.

	1. Cornwall.	2. Bourg d'Oisans.	3. Bourg d'Oisans. Rammelsberg.
SiO_2	42·10	41·53	43·46
Al_2O_3	17·40	17·90	16·33
Fe_2O_3	3·06	3·90	2·80
FeO	5·84	4·02	6·78
CaO	20·53	21·66	20·19
MnO	4·63	3·79	2·62
MgO	0·66	0·74	1·73
K_2O	---	---	·11
B_2O_3	4·64	4·62	5·61
H_2O	1·80	2·16	1·45
	100·66	100·32	101·08

The ratios from the results of analysis No. 2 are: $SiO_2 : Al_2O_3 + Fe_2O_3 : (\underset{11}{FeO+MnO}) + (\underset{40}{CaO+MgO}) : B_2O_3 : H_2O$—69 : 20 : 51 : 6 : 12—or 10 : 3 : 8 : 1 : 2—giving $B_2O_3 . 3R_2'''O_3 . 8R''O . 2H_2O . 10SiO_2$, or $BR_3'''R_4''H_2(SiO_4)_5O$. This expression will allow of the graphic formula:

$$\left.\begin{array}{l} Al \\ Al \end{array}\right\} \left\{\begin{array}{l} SiO_4 \equiv \\ SiO_4 \equiv \\ SiO_4 \equiv \\ SiO_4 \equiv \\ SiO_4 \equiv \end{array}\right\} \left.\begin{array}{l} Al \\ H_2 \\ BO \\ R_4'' \end{array}\right.$$

Which gives for the calculated composition considering all the R″ as calcium:

* Zeitschr. d. Geol. Gesellsch., xxi, 689.

Al_2O_3	20·9
SiO_2	41·1
H_2O	2·5
CaO	30·7
B_2O_3	4·8
	100·0

While these results differ from those deduced by Rammelsberg from his formula, they agree very well with all the results of analysis No. 2.

Although the Stromeyer and Marignac methods of estimating boric acid have been shown to be unreliable, and the determination of any constituent of a mineral by difference is unsatisfactory, nevertheless it will be seen, on comparing the results of the various analyses, that the directly determined percentages of boric acid do not differ greatly from the older values.

I have to express my sincere thanks to Professor F. W. Clarke, by whose kindness the material for these analyses was put at my disposal, and also to Mr. Washington for kindly furnishing the description of the colemanite.

Laboratory of U. S. Geological Survey,
Washington, D. C., June 8, 1887.

Art. XXXIV.—*The Texas Section of the American Cretaceous;* by Robert T. Hill.

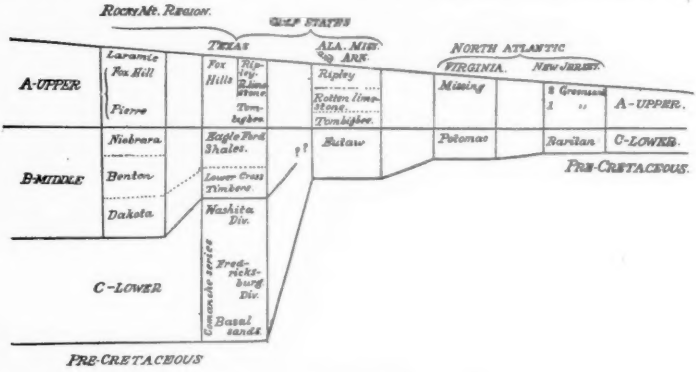
[Published by permission of the Director of the U. S. Geological Survey.]

It is necessary to make a brief preliminary explanation of the Cretaceous of the United States as it is generally understood through accepted publications. There are at least five widely separated areas where the system has been independently studied by different authors, but little or no work has been done to trace the direct stratigraphic relations between them. In each of these areas, except the Californian which will not be touched in this paper, the North Atlantic (including New Jersey, Maryland, District of Columbia, Virginia and the Carolinas), the Gulf (including Alabama, Georgia, Mississippi, Tennessee, Arkansas and eastern third of Texas), the Rocky Mountain (including the Trans-Pecos and lower Rio Grande region of Texas), the principal subdivisions recognized are those of the following table.*

There is evident from a careful study of the faunas and stratigraphy of these regions, throughout them all, within the

* In the following diagram the solid lines represent complete faunal breaks, and the dotted lines indicate subdivisions whose species range into the including formations.

limits which I have marked, a great similarity of molluscan fauna, both specifically and generically, although the lithologic and stratigraphic characters vary in each. To the local formations of this collection of strata many different names have been given, and nearly every horizon has been termed a "group" regardless of any specific definition of that word, which has been used with a indefinite meaning in all the nomenclature of



the American Cretaceous. Instead of indicating a plurality of related phenomena, it has usually been applied indiscriminately to single characteristics based upon lithologic or specific culminations. For instance, in the Alabama regions the "Tombigbee sands," the "Rotten limestone," and the Ripley beds have each been called "Groups," when in reality together they constitute but a single group, as interpreted by the present accepted meaning of that word, their lithologic features being the fluctuations of an unbroken sedimentation, and the molluscan fauna continuous or interwoven by connective species from top to bottom. The "groups" so-called are really "horizons," representing the culmination of species or sedimental variations. The same can probably be said of the New Jersey Cretaceous above the Raritan clays, and the Fox hills and Pierre "Groups of the Northwest." The entire collection of strata of this upper portion of the American Cretaceous together constitutes a group which has been correlated with the Upper Cretaceous of Europe, but until our stratigraphic studies are completed, can only be called the "Upper Cretaceous."

In the Rocky Mountain and Texas regions other marine formations exist, but they have not as yet been traced east of central Texas. These include the Benton, Niobrara and Dakota sandstone groups of Meek and Hayden, which the former geologists correlated, upon good reasons, with the Lower Chalk or Upper Greensand of Europe. The state of knowledge

concerning the American Cretaceous does not justify any more specific term to these as a whole than "The Middle Cretaceous."

In all four of the regions above mentioned the undoubted open sea or marine groups rest upon the problematical formations of more shallow sediments, consisting of clays and sands, unaccompanied by any distinctive molluscan faunas, but a great abundance of vegetal remains: such as the Dakota sandstone in the Rocky Mountain region, the Eutaw clays in the Alabama region, the Potomac beds in the Virginias, and the Raritan clays, in New Jersey the relation of which to each other has not been published and is still a fertile question for investigation.*

The Dakota sandstone was erroneously thought, by Mr. Meek, to be identical with the Raritan clays of New Jersey, and Professor E. D. Cope has suggested that the Lower Cross Timber or Dakota Group of Texas was equivalent to the Eutaw Group of Mississippi. These as well as the Potomac formation of Rogers in the Virginias, and the Raritan clays of New Jersey, have been placed separately by many writers at the base of the Cretaceous series. If the Lower Cross Timber sands be of the age of the Dakota sandstone, as has been asserted by Shumard and others, and since when present they rest directly on top of this division, then we have in Texas not only the whole section of previous writers often visible in connected exposure, but a new and lower group of the marine Cretaceous beneath the hitherto recognized groups.

In this Journal of January, 1887, I first called attention to the fact that the current ideas of the relations of the Cretaceous strata of Texas were erroneous. In a paper read before the Philosophical Society of Washington,† January 29, 1887, I published a local section, typical of the whole region, including the strata from the Tertiary to the Carboniferous, and a condensed summary of the paleontology, stratigraphy and literature of the Cretaceous strata of Texas. I demonstrated the transitional position these strata occupied between the Atlantic States bordering upon the Gulf of Mexico and those of the Rocky Mountain region, and showed the existence there of a deep marine group of the Cretaceous which is older than any hitherto recognized on this continent. In a paper read before the Philadelphia Academy of Science, February 5, 1887, Dr. C. A. White published a résumé of the section furnished him by me for that purpose together with some brief deductions thereon and some correlations of his own. In the present

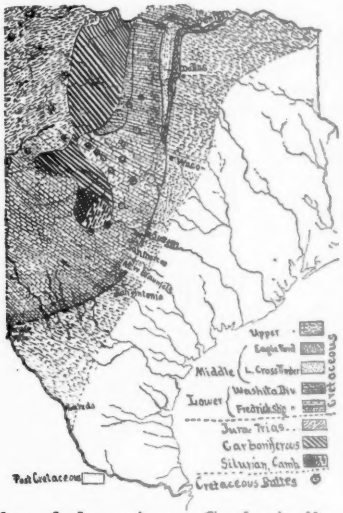
* Some important unpublished observations, which the writer does not feel authorized to use, have been made of late in these basal groups by McGee, Fontaine, Smith, Johnson and others.

† "The Topography and Geology of the Cross Timbers and Surrounding Regions of Northern Texas." See this Journal, April, 1887.

paper, to which the former was but introductory, I propose to diagnose more clearly this lower group and to explain many new features of it which throw much light upon the American Cretaceous section.

The strata of the Cretaceous period in the Texas region are so uniform and simple in their deposition, and the exposures and contacts of the groups so well marked, that they would be easily described, had not the publications by early writers * involved it in much confusion.

In the paper upon the Topography and Geology of the Cross Timbers, I showed how the westward extension of the upper Cretaceous from the other Gulf States abruptly ended along a line commencing in the vicinity of old Fort Washita, Indian Territory, and how it extended, as shown upon the accompanying map, from that point a little west of the cities of Denison, Sherman, McKinney, Dallas, Waco and San Antonio, and through the cities of Austin, San Marcos and New Braunfels, to a point eighteen miles west of Eagle Pass where it crossed the Rio Grande into Mexico. In addition to being the line of demarcation between the upper, the middle and lower groups of the Cretaceous formation, it is the western limit of the fertile Black Prairie Region, and separates the reliable agricultural from the grazing region of Texas; a complete change in the topography, meteorology and other natural conditions taking place when the line is crossed into the central denuded region. Geologically it is one of the clearest and sharpest lines of demarcation in America, and along it is to be seen what I believe the most comprehensive section of the Cretaceous formation to be found on this continent.



The Austin New Braunfels Non-conformity.

I have previously shown that along the northern third of this boundary line the country was generally level, with a uni-

* The writer has made a careful compilation of the literature of the geology of Texas, and endeavored to make a complete reference book for those who wish to trace the development of geological knowledge in that region. See Bulletin No. 45, U. S. Geological Survey. (In press.)

form slope of surface to the southeast, that the underlying strata dipped in the same direction at a slightly greater angle; and that the escarpment lines, originally light or obscure, which mark the eastward recession of the rapidly disappearing formation, faced to the westward. Farther southward the topographic features along each side the line are less easily distinguishable, as in the vicinity of Waco, McLennan County, and Salado, Bell County. South of the last named place, however, they again become sharp, but the escarpment line increases in prominence, and instead of facing westward faces to the east, so that extending from Georgetown, Williamson County, to far southwest of San Antonio, there is an abrupt step of several hundred feet, the general altitude of the country above sea level diminishing from twelve hundred feet to five hundred within a score of miles. This escarpment passes near the cities of Austin, San Marcos, New Braunfels, the Post Office of Heliotes, eighteen miles west of San Antonio, and from thence westward to Rio Grande. It has long been known as a geographic feature of the country. It was first described by Kennedy, and later more in detail by Roemer, whose labors in Texas were mostly in its vicinity, and who placed it on his map of Texas. The latter utterly misinterpreted its geological features however as will be shown later on. When viewed from the International and Great Northern railroad, which runs from Austin to San Antonio, east of and parallel to it, the scarp has an irregular and varying appearance, resembling a broken range of distant hills. East of and at the base of the scarp is a gentle undulating plane, averaging twenty miles in width south of the Brazos, and extending the entire length of the State, which I have described previously as the Black Prairie region.* The plateau surmounting the escarpment and extending for hundreds of miles to the westward, is an entirely different country. Instead of the gentle undulations of the Black Prairie, the topography, where other than level prairie, has the more sharply defined features of buttes and mesas; and instead of the wide flood plains and low banks there are steep banks and sometimes rugged cañons. The color of the soil and underlying rock, it is true, approximates that of the Black Prairie, but in composition, structure and geological age they are entirely different, facts which have been overlooked by most writers.

A careful study of this escarpment line and the stratigraphy of the adjacent formations reveals some most interesting results. The underlying structure of the Black Prairie region, as seen all along the foot of the escarpment, which is the same as at Dallas, consists of massive, soft, chalky limestones (*A*),

* This is the "gently undulating, or hilly region" of Roemer, and the "soft lime rock region" of Roberts.

locally called "White Rock," or "rotten limestone." It dips at a visible angle to the eastward, disappearing beneath the Marine Eocene about twenty-five miles east of the escarpment line. Along the east bank of Shoal Creek, in the western part of the city of Austin, and in the banks of two unnamed creeks, emptying into the south side of the Colorado, opposite Shoal Creek, these limestones are seen to abruptly terminate, and in several places to rest usually upon blue calcareous shales (*B*), containing an entirely different fauna. These shales, which are only visible when protected by the above-mentioned limestones, owing to rapid disintegration, in turn are seen to rest upon the hard, eroded surface of another limestone formation (*C*) which composes the beds of the creeks, and, dipping from the northwest at an angle of fully fifteen degrees, also forms the whole face of the escarpment and plateau. In places the soft, rotten limestone of the Black Prairie is seen to rest directly upon the disturbed harder limestone without intervention of the shales. The characteristic strata and fauna of the first-mentioned formation invariably terminates at the foot of this escarpment, so that it is not found west of these contacts, nor that of the harder limestones of the escarpment and plateau east of them, as shown in the following diagram:

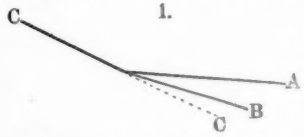


FIG. 1.—THE AUSTIN NEW-BRAUNFELS NON-CONFORMITY AS IT IS.—Contact seen on both sides of the Colorado River at Austin. *A*, Rotten limestone of Black Prairie region; *B*, shales; *C*. Lower Cretaceous limestone of escarpment and plateau.

There is a clear non-conformity between each of these divisions at Austin, both stratigraphically and faunally, not a single species extending from one division to the other, and the well-marked lithologic features of each terminating very abruptly. This non-conformity is clearly and unmistakably visible in and near Austin, San Marcos, Heliotes and New Braunfels; and this relation of the strata, which is the same along the face of the escarpment from Austin to Rio Grande, is diametrically opposite to that originally announced by Roemer (and accepted by Shumard and other writers down to the present day),* who made the Cretaceous of the plain at the

* But one author has ever published an opposite view to this relation of the strata. Professor E. D. Cope, in Bulletin No. 17 of the U. S. National Museum, makes the following statement, which, excepting its correlations, is true, but has apparently passed unnoticed. He says:

"An abrupt elevation commences somewhere to the southwest of Fort Worth and continues southward and westward, passing close to Austin, the State capital, and within twenty miles of the city of San Antonio, extending westward to the Rio Grande. The position of the limestone thus elevated is said to be older than that which occupies the adjoining lowlands, being correlated by some geolo-

foot of the highlands (*A*) older than that of the plateau, and to extend under it as shown in the following diagram. This error, which was the fundamental cause of the confusion of knowledge concerning the Texas cretaceous formation, has existed since Roemer's time.*

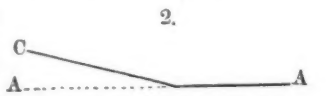


FIG. 2.—THE AUSTIN NEW-BRAUNFELS NON-CONFORMITY, as Roemer thought it. *A*, Rotten limestone of Black Prairie Region ("Kreidebildungen am Fusse des Hochlands," Roemer), supposed by Roemer to extend under the escarpment. *C*, Lower Cretaceous of escarpment and plateau, supposed by Roemer to rest on *A*.

Upon investigation of the three divisions of strata along the Austin New Braunfels non-conformity, the rotten limestone group of the Black Prairie Region at its foot, the harder chalky limestones of the scarp and plateau, and the intervening shales exposed along their contact, the following facts are apparent.

The Upper Division of the Texas Cretaceous.

The Rotten limestone† underlying the Black Prairie is a deep marine formation of much uniformity. Its strata are of great thickness and constitute a well-defined group. They are over 1500 feet at Spofford's Junction, as determined by artesian borings, and over a thousand in the Dallas and Austin regions.

The limestone of this upper formation, and its included yellow marls, extend into Arkansas and Mississippi on the north and Mexico on the south. The lower portion is composed of uniform sediments of deep marine origin, containing few molluscan remains, except giant Inocerami and a small Gryphæa-like Ostrea, found also in the Fox Hills and Pierre of Meek and Hayden, and Tombigbee sands and Rotten limestone of Hilgard, the exceedingly numerous varieties of which have been described under at least a dozen names‡ in different reports.

gist with the No. 2 of Meek and Hayden, while the lower part of the formation is said to represent No. 3. Without criticising their determination it may be observed that the fault which should exist has been observed at various lines along the elevation. I found it crossing the Heliotes Creek, eighteen miles west of San Antonio, at a locality pointed out to me by Mr. Gabriel W. Marnoch."

* Roemer confessed (see "Texas,") that he had not seen this contact, and that his conclusions, here shown to be erroneous, were based upon hypotheses. This was the fundamental and radical error in his otherwise excellent work.

† Roemer did not separate these limestones from the underlying shales, but described them together as the Cretaceous at the foot of the highlands, and erroneously thought, as shown on a previous page, that they extended under instead of resting unconformably upon the limestones of the escarpment. Shumard failed to detect Roemer's error, and fell into the same mistake. The two are easily separated in Roemer's writings by interpreting his careful descriptions of the strata and fauna of the waterfall and the ford near New Braunfels.—Kreidebildungen von Texas, p. 11.

‡ *Gryphæa Aucella* (Lamck.) Roemer; *G. vesicularis* Roemer (not Lamck.); *G. Pitcheri* Hilgard, not Mort.; *Ostrea patinia* M. and H.; *G. mutabilis* Con.; *O. Anomioformis* Hilg., not Roemer, most of which and many more varieties inseparably occur in the same localities.

The strata of the upper half become thinner and thinner and the fauna assumes a more littoral aspect toward the top, as in the Ripley beds of Tippah Co., Miss., the Navarro beds of Texas and the Fox Hills of Meek and Hayden. Along the lower Rio Grande the strata meet, and are either covered by or become identical with other strata having the lithologic and faunal characteristics of Meek and Hayden's No. 4 and 5, and which are the direct geographic continuation along the face of the Rocky Mountain axes of the same formation as exposed in New Mexico and Colorado.

Concerning this and all the following groups it is but proper to remark that the paleontology of Texas is of an unsatisfactory nature, and that none of it has been done or revised in accordance with modern biologic methods. Dr. Roemer's paleontologic descriptions are models of descriptive excellence, and it is easy to trace whatever element of error may occur in them, but the writings of most other writers have been fragmentary and unsatisfactory, being unaccompanied by any definite horizon or locality. Many of the fossils from Texas described by men who have never visited the State, convey no idea of their geological horizon, and several of the most common forms have been confusingly re-described. Most of the names given were in the days when species-making was looked upon as the chief accomplishment of the paleontologists, and resemblances were oftentimes intentionally ignored in order to add new names to the category. It was in this manner that many of the fossils from Texas have been twice, sometimes thrice, described under different names by separate authors. The latest descriptions of Texas Cretaceous fossils describes three alleged new genera, one of which had been described over a year ago under another name.*

With the assistance of the author's description, verified by years of personal investigation, I have recognized the following fossils† belonging to this upper grand division of the Cretaceous in Texas.

Nodosaria texana Con.
Terebratula guadalupæ Roem.
Hemiaster (*Cassidulus*) *parastatus* Mort., Desor.
Hemiaster texanus Roem.
Exogyra costata Say.
Exogyra costata, var. *ponderosa* Roem.
Exogyra fragosa Con.
Exogyra læviuscula Roem.
Exogyra subspatulata Roem., Con.
Gryphæa aucella Roem.
Ostrea Lyonsii Shum.
Ostrea Owenana Shum.
Ostrea planatovata Shum.

* See Proc. Philad. Acad. Nat. Sci., Feb., 1887.

† These lists are not the result of guess-work, but of the most careful stratigraphic observations and compilation. It has been my endeavor for years to learn the exact stratigraphic horizon and range of the numerous fossils described from Texas, few of which were accompanied by any stratigraphic data.

Ostrea bellaplicata Shum.
Ostrea Blackii White.
Spondylus guadalupæ Roem.
Lima crenulicosta Roem.
Pecten burlingtonensis Shum.
Pecten Nilssoni Goldf., Roem.
Pecten simplicus Shum.
Pecten virgatus Nills, Roem.
Arca vulgaris.
Arca sublongata Con.
Trigonia thoracia Mort.
Cardita eminula Con.
Lucina parvalineata Shum.
Cardium congestum Con.
Cardium choctawense Shum.
Liopistha elegantula Roem.
Pachycardium Spillmani.
Cytherea.
Linearia cancellato-sculpta Roem.
Mactra texana Con.
Mactra alta M. and H.
Mytilus semiplicatus Roem.
Anatina sulcatina Shum.
Panopæa subplicata Shum.
Pholadomya Lincecumi Shum.
Pholadomya tippana.
Inoceramus Mort.
Inoceramus confertim-annulatus Roem.
Inoceramus crispii Mant.
Inoceramus crispii Mant.; var. *sulcatina* Whitfield.
Inoceramus striatus Mant., R'm.
Inoceramus biformis.
Avicula planiuscula Roem.
Legumen elliptica.
Siliquaria biplicata.
Radiolites austinensis Roem.
* *Cylichna secalina* Shum.
* *Cylichna striatella* Shum.
Anisomyon Haydeni Shum.
Turritella corsicana Shum.
Turritella irrorata Con.
Turritella Winchelli Shum.
Eulima? texana Roem.
Scala bicarinifera Shum.
Scalaria Forsheyi Shum.
Chemnitza? texana Roem.
Ficus subdensatus.
Pleurotoma ripleyana.
Pyrula, sp. ind.
Rapa supraplicata.
Purpurea cancellaria.
Solidula Riddelli Shum.
Strombus densatus.
Chemnitza gloriosa Roem.
Volutithes? navarroensis Shum.
Rostellites texanus Con.
* *Ringicula pulchella* Shum.
Nautilus elegans Sow., Roem.
Nautilus Dekayi.
Baculites anceps Lamck.
Baculites annulatus Con.
Baculites asper Mort., Roem.
Baculites spillmani.
Baculites tippaensis.
Turrilites splendidus Shum.
Turrilites helicinus Shum.
Scaphites verrucosus Shum.
Helicoceras navarroensis Shum.
* *Ptychoceras texanus* Shum.
* *Ammonites dentato-carinatus* Roem.
Ammonites flaccidicosta Roem.
Ammonites guadalupæ Roem.
Ammonites pleurisepta Con.
* *Ammonites texana?* Roem.

* Fossils marked thus are doubtfully placed here.

A careful comparison of the above list, which is mostly in the nomenclature of the original descriptions, with similar lists published by different authors from New Jersey, Alabama and Mississippi, and the Rocky Mountain region, shows that nearly a third of the forms can be reduced to synonyms and that fully three-fourths of the species are common to the Upper Cretaceous of these regions, and that the faunal cessation at its base is as clearly marked. The writer does not believe in general correlations, but Mr. Meek has clearly shown the con-

tinuity of this fauna from New Jersey to the Rocky Mountain region: and I believe that both faunally and stratigraphically, this Cretaceous, at the foot of the highlands, is the direct geographic and geologic continuation of the Upper Cretaceous of the United States in general, and of the Gulf States region in particular, including the so-called "Rotten limestone," "Ripley," and Tombigbee Sand groups of Hilgard and the "Fox Hill," the Fort Pierre, and perhaps the upper Fort Benton groups of Meek and Hayden. This group of strata taken as a whole, from New Jersey to British Columbia, is the upper division of the American Cretaceous, and, as has been so frequently expressed by Vanuxem, Lyell, Pictet, Meek, and others, is the representative of the Upper or White Chalk of Europe.

Middle Division of the Texas Cretaceous.

The middle division of this Austin section (B) consists of argillaceous shales and a few thin bands of limestones and is but a fragment of the same formation more fully developed northward. Careful investigations have not been made to show the conformity with the overlying group, but faunally and lithologically there is no transition between them in the Austin region. Dr. B. F. Shumard, without having recognized their identity, gave these shales two positions in the composite section† which he made up of his brother's, Dr. Riddell's and his own observations in widely separated portions of the State. The first of these was at the base of and included in his Austin limestone, as he had noticed them at Austin, and the other was the "fish beds" which, upon his brother's representations with the marly clay or Red River group, he erroneously placed at the base of his section.‡ There is no record that Dr. B. F. Shumard, ever visited the Denison region himself and this duplication and misplacement of the various members of his section is due to this fact.

I have traced the continuity and identity of these shales with the Eagle Ford horizons of my section, and have seen them resting by most perfect contacts upon the top of the Lower

*Sir Charles Lyell expressed the opinion that the fossils of the New Jersey Cretaceous beds of which this division is the equivalent, on the whole agree most nearly with those of the upper European series from the Maestrich beds to the Gault inclusive. In his Cours Elémentaire de Paléontologie, Alcide d'Orbigny refers the New Jersey beds as well as those of Nebraska (Upper Missouri), Arkansas, Texas (Rœmer's classification), and Alabama, all to his Senonian, the equivalent of the White Chalk and Maestricht beds of the old world.

Pictet, in his Traité de Paléontologie, also refers most if not all of the New Jersey Cretaceous fossils to the era of the White Chalk of Europe. See Cretaceous Paleontology, Meek. pp. xliii-xlvii.

†Trans. St. Louis Acad. Science, vol. i, 1860.

‡I have explained the error in a review of Dr. G. G. Shumard's Red river observations. See this Journal, Jan. 1887.

Cross Timber (Dakota) beds in the Denison region, or, where the latter are absent, as at Austin, owing to erosion or non-deposition, directly upon the Comanche series, which demonstrates their position to be in the middle, and not at the bottom of the Texas Cretaceous as B. F. Shumard placed them. I have verified by personal observations the occurrence of most of the following forms in these shales at Austin and Eagle Ford, and New Braunfels:

Ostrea congesta.
Ostrea anomiaformis Roem.
Exogyra columbella Meek.
Lucina sublenticularis Shum.
Lucina (Cyprimera) crassa Meek.
Avicula irridescens Roem.
Inoceramus mytilodes Mant. Roem.
Inoceramus problematicus Schlot
Inoceramus deformis M. & H.
Scaphites semicostatus Roem.
" *texanus* Roem.
Ammonites percarinatus Meek and Hall.
**Ammonites graysonensis* Shum.
**Ammonites Meekianus* Shum.
Barbatia Shum.
Arca, sp. nov.?
Anomia, sp. ind.
And many fish remains.

The relative position, identity of faunal and lithologic features, and much stratigraphic data confirm the opinion previously expressed, that they are the equivalent of Meek and Hayden's 2 and 3, or Niobrara and Benton. I believe them to be the direct geographic continuation of the same geologic sediments, especially as seen by Newberry in northwestern New Mexico, together with the underlying Dakota sandstone which are represented by the Lower Cross Timber beds in northern Texas.

The contact of these shales with the over- and underlying groups is beautifully displayed along the south banks of the Colorado, opposite Austin; and in the east bank of Shoal Creek in the city itself, where there is a complete faunal and stratigraphic break between the shales just as Meek observed between the Pierre and Niobrara beds in the northwest and of which it can truly be said here as he said of the same formations there, that "the most strongly marked paleontological break in the Upper Cretaceous section is at the line separating the Niobrara from the Fort Pierre group, and that the beds above this horizon represent the upper or White Chalk and those below it the lower or gray chalk and perhaps also in part the Upper Greensand of English geologists."*

No equivalent of this division is found east of the Texas region, only a few of the vertebrate fish remains, belonging to species that have a wide geologic range, having been found in the Gulf and north Atlantic regions. This fact adds confirma-

* Cret. Pal., xlvi, xlvii.?

tion to a theory of the considerable hiatus between the deposits of the basal Eutaw clays and part of the Mississippi section above them.

The Lower Cross Timber series (Dakota sandstone of Shumard, Trans. St. Louis Acad., vol. ii, 1862) which underlie these shales in northern Texas, are entirely missing south of Waco, and hence do not appear at Austin. Whether this is due to their having been eroded away before the deposition of the shales, or to their having never been deposited, the writer does not feel prepared to state.

I have also traced the continuity of the Lower Cross Timber (Dakota sandstone?) division from the Texas Pacific railroad to Red river in the vicinity of Denison, and demonstrated their identity with the arenaceous group of Shumard's section, which with the so-called Marly clays he placed erroneously at the base of the whole Texas section. A year after the publication of his original section Dr. Shumard decided these arenaceous beds to be equivalent to the No. 1 (Dakota sandstone of Meek and Hayden.)

Concerning the relative age of the Dakota sandstone of the Rocky Mountain region, with which these beds in Texas are probably identical, Meek says: "Up to this time we also know of no single species being common to it and any of the beds above; but then we as yet know but comparatively few species of animal remains from this rock; one of these, however, belongs to the Cretaceous genus Leptosolen while the other shells are allied to Cretaceous species and unlike Jurassic forms. In addition to this the modern affinities of the numerous leaves of the higher types of dicotyledonous trees found in it, present a strong objection to the adoption of the conclusion that it may belong to a lower horizon than the Upper Greensand of British geologists; while its position directly below beds almost beyond doubt representing the lower or Gray Chalk, precludes its reference to any higher stratigraphical composition. Consequently we have long regarded it as most probably representing in part, if not the whole, of the Upper Greensand." The fossils described by Dr. B. F. Shumard from the Red river country include forms from horizons between the basal portion of the Rotten limestone of Division A, such as the *Ostrea belliplicata*† Shum. (including the Eagle Ford shales at the Lower Cross Timber beds) and from the top portion of the Comanche series, such as *Ammonites Swallovii*, etc. These horizons have not been fully studied but they represent all the

* In the vicinity of Denison the upper part of the Comanche series, the Lower Cross Timber sands, and the Eagle Ford shales succeed each other almost inseparably, so that there, instead of the sharp lines of demarcation between the three groups as at Austin, we have a gradual transition between all the beds.

† *Ostrea Blackii*, of White.

sediments between the well defined upper and lower deep marine groups and they constitute the middle division of the Cretaceous. I therefore present their fauna as a whole without detailed attempt at separation.

Ostrea anomiaformis Roem.
Ostrea congesta Con. ?
Ostrea bellaplicata Shum.
Ostrea Blackii White.
Exogyra columbella Meek.
Barbatia, sp. nov.
Cucullæa millestriata Shum.
Nucula bellastriata Shum.
Nucula Haydeni Shum.
Nucula serrata Shum.
Lucina sublenticularis Shum.
Cyprimera crassa Meek.
Crassatella parvula Shum.
Dione ("*Cytherea*") *lamarensis*,
Tapes Hilgardi Shum.
Venilia (*Cyprina*) *Laphami* Shum.
Venus sublamellosus Shum.
Corbula Tuomeyi Shum.
Gervilia Mudgeana White.
Gerviliga regaria Shum.
Aguilluria? Cumminsi White.
Avicula irridescens Roem.
Inoceramus capulus Shum.
Inoceramus mytilopsis Con.
Inoceramus mytiloides Mant.
Nearea alæformis Shum.
Inoceramus problematicus Schlot.
Cylichna minuscula Shum.
Neritopsis biangulatus Shum.
Tornatella texana Shum.
Ringicula acutispira Shum.
Ringicula subpellucida Shum.
Scalaria lamarensis Shum.
Cerithium, sp. nov.
Baculites gracilis Shum.
Scaphites semicostatus Roem.
Scaphites texanus Roem.
Ancyloceras annulatum Shum.
Ammonites percarinatus M. & H.
A. Graysonensis Shum.
A. inaequiplicatus.
A. Meekianus Shum.
A. Swallovii Shum.
Fish remains.
Dicotyledonous leaves.

The Lower Division of the Texas Cretaceous.

The harder limestones, seen underneath the Lower Cross Timber beds at Fort Worth and Denison and the shales at Austin, and forming the face and plateau of the escarpment, are the undoubted top of the Comanche* series of my former paper. This great formation, which constitutes the face of the escarpment and the great plateau at its top, covers or once covered the whole of the central region as far west as the Rocky Mountain region. This group of strata embraces thousands of feet of deep marine sediments and extends over an immense area in Texas. At San Marcos, New Braunfels, Austin, and many other places throughout the central region, the strata are beautifully shown. Four miles northwest of the latter city the banks of the Colorado afford a vertical exposure of over 700 feet, and yet these are only the topmost strata of

*The name Comanche is given to this series owing to the fact that it was at the town of that name that I first studied it, and that the Central Denuded Region of Texas, where the formation is found, was the home of the Comanche Indians.

the series. The strata dip rapidly to the southeastward. While resembling the Rotten limestone of the Black Prairie region in color, a fact which has prevented its differentiation by previous observers, they are entirely different in hardness, structure, stratification, and all other respects*. The strata consist of white and yellow limestones, greatly varying in hardness, somewhat subcrystalline or chalky in places, and under a lower power they are seen to be composed of minute loosely-cemented calcite crystals and occasional Foraminifera. Toward the basal portion there are some thin bands of firm gray crystalline limestones, much resembling quartzite in firmness and opalescence. Between the limestone strata there are usually white calcareous marls or shales, of nearly the same color. Sometimes there are horizons of flint nodules, and rarely beds of pulverulent chalk. The thickness of the individual strata vary from over a hundred feet at the mouth of the Pecos river, to less than one foot in the vicinity of Fort Worth and Denison. The rock structure of this lower formation, although crumbling far more readily, does not yield as easily to solution as does that of the Upper Cretaceous of the Black Prairie region. It breaks into fragments under the expansion and contraction incident to daily extremes of temperature, to which fact is due the rugged outlines of the buttes, mesas and cañons in the central or denuded region as opposed to the gentle undulations of the Black Prairie region where the exposures of this formation in Texas are found.

The Central Denuded Region.

The borders of the central region in which the Comanche series is found present varying sharpness. The northern half is bounded upon the west by the westwardly receding line of the Llano estacado, and upon the east by the eastwardly receding line of the Rotten limestone of the Upper Cretaceous of the Black Prairie region. This recession of the borders in opposite directions is not apparent in the southern half of the region, where the denudation has not degraded and removed the harder limestones which constitute the eastward faces, scarp and plateau of the Austin New Braunfels non-conformity of the eastern boundary to the level of the Black Prairie region, as has been done along the northern portion of the same edge, while the former scarp of the staked plains has been entirely removed along the southern half of the western border.

* Governor Roberts, although utterly unaware of the geologic relation, is the first man who clearly noted this difference and fitly distinguished the two regions as the "soft" and the "hard" lime rock regions, respectively. See "A Description of Texas; its Advantages and Resources," by Oran M. Roberts. St. Louis, 1881.

Within the Central denuded area this newly defined group of the American Cretaceous is beautifully shown, every foot of its thickness and that of the Paleozoic strata upon which it generally rests, having been exposed by the excessive atmospheric denudation, showing its contacts with the over- and underlying formations. The process of this denudation in Texas is exactly similar to that of the high plateaus of Utah and Colorado, and the description given by Powell of aridity and erosion in his "Exploration of the Grand Cañons of the Colorado," pp. 170–171, is equally applicable to it, except that here in Texas the sudden heavy rainfalls are more frequent, and the different resistance of the sedimentary rocks causes a difference in topographic effect. In my paper on the Cross Timbers I have sufficiently described the northeast quarter of this central region and shown how the strata in going from east to west, are successively exposed in descending series from the marine Tertiary to the Paleozoic. The latter are exposed along a north and south axis, from the Red River to Colorado, by the removal of the overlying Cretaceous. The northwest quarter of the region is occupied by the red beds, or alleged "Jura-Trias," with occasional patches of the Cretaceous preserved upon it, in the shape of isolated buttes.

The southern half is still covered by the chalky limestones of the Comanche series of the Cretaceous, which, in addition to having been thicker originally than in the northern portion, have not suffered so much from the destructive denudation. The thickness of this formation rapidly decreases to the northward and I am inclined to believe that the strata in Texas and the Indian Territory represent only the northern shallowing of the great sediments developed more fully in Mexico and Central and South America. The thickness of the Comanche series, while not exceeding 500 feet along the Fort Worth section, at Austin must be fully 2,000, and still farther southwestward I believe it must approach 5,000. In the southern portion of the region the individual strata, as seen at the mouth of the Pecos river, are hundreds of feet in thickness; at Austin the thickest strata do not exceed fifteen feet, while at Fort Worth and Denison they seldom reach two feet. The members of this series possess sufficient diversity to divide it into many minor divisions, but this should not be attempted until several years more of thorough stratigraphic study of the whole is made. Provisionally I have divided it into a lower and upper division which are called the Fredericksburg* and the Washita

* See "Texas" and "Kreidebildungen von Texas?" for the first descriptions of the Fredericksburg strata, by Dr. Ferd. Roemer. The Washita strata are first mentioned by Dr. G. G. Shumard in Marcy's Exploration of the Red river of Louisiana, but better defined by Marcou in the Pacific Railroad Report of the 32° Parallel, octavo edition.

divisions after the typical localities of each, and where they were first noticed and described. While there is a great faunal and stratigraphic continuity between these two temporary divisions, nearly every species of the essentially deep sea fauna has a horizon of greatest culmination which will serve as land marks to the perfect section of the future. There are also certain specific differences between the faunas of the two divisions that mark them well, each having many characteristic forms of its own.

The Washita Division.

The upper half or Washita division is preserved only in a limited belt, seldom exceeding twenty miles in width, adjacent and parallel to the western border of the Black Prairie region. Its strata are the same as mentioned but not defined by Roemer from the Waco camp,* ten miles west of New Braunfels, by Dr. B. F. Shumard at old Fort Washita, Indian Territory, from which it takes its name,† and as has been more fully described by Jules Marcou from Comet creek, in the same vicinity. I have traced the formation from the vicinity of Fort Washita to San Antonio, and have good authority for its occurrence westward of the latter place to the Rio Grande, beyond Eagle Pass. The strata are of great uniformity of deposition, throughout, except that they are thinner in the northern portion of the exposures, where, from Fort Worth to Fort Washita, and especially at Denison, they make a gradual transition from deep-sea limestones to alternating limestones and shales, and then from shales to the littoral sand and clay deposits of the Lower Cross Timbers (Dakota Sandstone?), representing the termination of the long period of deep-sea sediments that marked the Comanche series. The following fossils have been found in this Washita division of the Comanche series, as far as I have been able to verify by careful field investigation:

Fauna of the Upper, or Washita Division.

Astrocœnia guadalupæ Roem.
Terebratula wacoensis Roem.
T. choctawensis Shum.
T. leonensis Con.
Holaster simplex Shum.
Holaster comanchesi Marcou.
Toxaster elegans Shum.
Cidaris hemigranosus Shum.
Pyrinia Parryi Hall.
Ophioderma? sp. nov.
Ostrea carinata Lam., Roem.
Exogyra arietina Roem.
Plicatula incongrua Con.
Ostrea crenulimargo Roem.
O. quadriplicata Shum.
O. diluviana Linn., White.

* "Texas," pp. 377; Kreidebildungen von Texas, p. 18.

† Dr. B. F. Shumard partially described this division, but misinterpreted its stratigraphic position in his section.

O. Marshii Marcou.
O. subovata Shum.
Gryphæa sinuata, var. *americana* Marcou.
Exogyra Valkeri White.
Gryphæa Pitcheri Mort.
var. *navia* Con.
var. *forniculata* White
var. *dilatata* Marcou.
Lima wacoensis Roem.
L. leonensis Roem.
L. Kimballi Gabb.
Neithea occidentalis Con.
Pecten quadricostatus Roem.
P. duplicostatus Roem.
Neithea cometa D'Orb.
? N. Wrightii Shum.
Janira fleuriausiana D'Orb.*
Lucina, sp. ind.
Trigonia, sp. ind.
Cardium hillanum Sowb.
Astarte texana Con.
Slearnsa? *robinsi* White
Crassatella lineata Shum.
Gervillopsis ("*Dalliaconcha*") *invaginata* White.
Panopæa subparallela Shum.
Panopæa texana Shum.
Pachyma austinensis Shum.
Pachyma? compacta White.
Pinna, sp. ind.
Inoceramus, sp. ind.
Caprina crassifibra Roem.
Caprina guadalupæ Roem.
Caprina occidentalis Con.
Caprina planata Con.
Caprina quadrata Con.
Caprina texana Roem.
Requienia texana Roem.†
R. bicornis Meek.
R. patigiata White.
R. Romeri Gabb.
Hippurites texanus Roemer.
Natica? (*Tylostoma?*) *prægrandis* Roem.
Nerinea, sp. ind.
Pleurotomaria austinensis Shum.
Turritella marnochii White.
Cinulia, sp. nov.
Apporhais, sp. nov.
Nautilus neocomensis D'Orb.
Hamites Fremonti Marcou.
Ancyloceras, sp. nov.
Turrillites brazosense Roem.
Ammonites acutocarinatus Roem., Shum.
Ammonites Belknapi Marcou.
A. brazosensis Shum.
Ammonites geniculatus Lea.
Ammonites leonensis Con.
Ammonites Shumardi Marcou.
Ammonites Swallovi, Shum.
Ammonites vespertinus Mort.
A. texanus? Roem.

The Fredericksburg Division.

The provisional line of geologic demarcation between the two divisions is the Caprina limestone of Shumard. This is the horizon of greatest resistance in the Comanche series. It consists of more massive and firmer semi-crystalline limestones than those above and below it, and does not yield so readily to denudation, so that it is preserved in many places as the cap-rock of extensive mesas and buttes. Wherever it is preserved there will be found below it the strata which have been sufficiently described by Roemer from near Fredericksburg, consisting of softer crumbling, gritty limestones and lime marls. These strata were also well described by Shumard as the

*I have found this form at Austin, and see no reason for making it a new species.

† Probably identical with *Caprotina lonsdalli* D'Orb.

"Caprina limestone," the "Comanche Peak Group," and the "Caprotina" (Requiena) limestone, and his sections of Packsaddle Mountain, Burnet County, and Comanche Peak, Hood County, will apply to this division wherever it is exposed, as it is of great uniformity throughout.

The buttes or mesas of Central Texas, where the best exposures are found, locally mistermed "mountains" and "peaks," are unique and peculiar to the region through which they are distributed. They are low, truncated protuberances, usually circular in outline. Their tops are invariably flat, and the sides generally slope at an angle of forty-five degrees. They seldom exceed three hundred feet above the surrounding level, and are the most prominent landmarks of the region. The chief of these are Comanche Peak, Hood County; Johnson's Peak, Bosque County; Round Mountain, Comanche County; Santa Anna Peak, Coleman County; Kiowa Peak, Hardeman County; Castle Mountains, Tom Greene County; Double Mountains, on the head waters of the Brazos; Antelope Hills, on the boundary of the Panhandle and Indian Territory; Packsaddle Mountain, Burnet County; Church Mountain, Runnels County, and hundreds of others. In geological and general features they are all alike, being remnants of a great formation that once covered the whole region. Their simple structure consists of perfectly horizontal deep marine sediments, the cap stratum of which is the hard Caprina limestone of Shumard (siliceous limestone of Roemer). This Caprina limestone occupies a very low horizon in a Cretaceous section, and it is evident that structurally it is a plane of greatest resistance of the Fredericksburg series, which covers, and was once covered by, softer strata than its own. Most of them are situated in the deep, worn river valleys, or around the edge of the Paleozoic exposures. They usually stand upon a level prairie region of limited extent, which are underlaid by thinner and firmer limestones, constituting another plane of resistance. When the latter is worn through, the Carboniferous, Jura-Trias, or whatever formation underlies the Cretaceous at the particular locality, is soon exposed. The section of Packsaddle Mountain, Burnett County, made by B. F. Shumard is almost identical with the other buttes wherever I have examined them. This uniformity over so wide an area is owing to the uniformity of the sediments.

The following fauna, which is a revision of that first published by Roemer from Fredericksburg, and by Shumard from the three synonymous divisions of his section, before mentioned, is found in this lower provisional division:

Fauna of the Lower or Fredericksburg Division.

Orbitulites texanus Roem.
Gryphæa Pitcheri Mort. (Type form.,
G. Pitcheri Mort.? Marcou.
Exogyra texana Roem.
Ostrea, sp. ind.
Anomia, sp. ind.
Janira occidentalis Con.
Cardium brazosense Shum.
Cardium Hillanum Sow.
C. texanus Con.
C. coloradoense Shum.
C. multistriatum Shum.
C. sancta-sabea Roem.
Cytherea? Shum.
Pholadomya sancta-sabæ Roem
Pholadomya pedernalis Roem.
Lima wacoensis Roem.
Arcopagia texana Roem.
Cypricardia pedernalis Roem.
Trigonia crenulata (?) Roem., Lam.
Solen irradians Roem.
Astarte lineolata Roem.
Cardita eminula Con.
Avicula convexo-plana Roem.
Avicula pedernalis Roem.
Mytilus tenuitesta Roem.
Homomya alta Roem.
Corbula occidentalis.
Corbis, Roem.
Modiola concentrico-costellata Roem.
Modiola pedernalis Roem.
Pinna, sp. ind., Roem.
Leda, sp. ind., Roem.
Venus, sp. ind., Roem.
Thracia, sp. ind., Roem.
Panopara Newberryi Shum.
Actæonella dolium Roem.
Scalaria texana.
Phasianella? perovata Shum.
Phasianella tumida.
Globiconcha coniformis Roem.
Globiconcha? elevata Shum.
Rostellaria (*Eulima*) Shum. *subfusiformis.*
Natica (*Lunatia?*) *pedernalis.*
Natica? (*Lunatia*) *acutaspira* Shum.
Nerinea acus, Roem.
Nerinea, sp. ind., Roem.
Avellana? texana Shum.
Turritella, seriatim-granulata Roem.
Cerithium? bosquense Shum.
Cerithium? sp. ind., Roem.
Pleurotomara, sp. ind., Roem.
Solarium? sp. ind., Roem.
Heteraster (*Toxaster*) *texanus* Roem.
Holectypus planatus Roem.
Cyphosoma texana Roem.
Pseudodiadema texana Roem.
Ammonites acuto-carinatus Shum.
Ammonites? pedernalis von Buch (not Binkhorst).

The basal contacts of this division have been observed in numerous places, and present many variations. West of the 99th meridian it usually rests upon the red beds of the Jura-Trias. East of this it usually rests directly upon the undoubted Carboniferous, excepting in the Archæan area of Burnett and surrounding counties, where, according to Mr. W. F. Cummins, it can be seen resting on the Carboniferous, the Silurian, the Cambrian, and in places upon the granite, all of which shows an eroded exposure of many formations previous to the subsidence resulting in its deposition. In the trans-Pecos region the formation may be seen resting upon the almost vertical strata of the upturned Paleozoic. The basal, or Dinosaur sands of my section, which are interpolated

between the Fredericksburg division and the undoubted Carboniferous, are the shore detritus of the Mesozoic sea when it bordered upon the Carboniferous continent. The lowest marine fauna of this division is seen in Parker county and careful study of the same may prove Jurassic affinities.

Several years of most careful study of the stratigraphy of the whole of the Comanche Series fully confirms its position to be lower than the strata of the Lower Cross Timber beds, which Shumard, White and other authorities have asserted to be identical with the Dakota Sandstone of Meek and Hayden, and hence lower than any of the hitherto described marine groups of the American Cretaceous. The fossils of the upper division are in most cases well preserved, and the species readily distinguishable. Those of the lower division are very poorly preserved, especially the bivalve mollusca, the shell structure having been destroyed, rendering it exceedingly difficult to obtain even the generic characters.

There is an apparent continuity of interlocking faunas throughout the series, and a few forms, such as *Cardium* (*Protocardia*) *hillanum* and its allies, *Neithea occidentalis* Con., and the *Gryphœa pitcheri* Mort., range throughout. A remarkable fact, however, is that with the exception of the last mentioned fossil, not a single species is known to pass from the Comanche series into the upper formations, and even this is not positively known to do so. The only other fossil which is ascribed to the Upper Cretaceous is the *Ammonites pedernalis* VonBuch, which has been confounded by some authors with the *Placentaceras lenticularis* of Meek, a form characteristic of the Upper Cretaceous of nearly all the world. It is an entirely different species however, as has been shown by Mr. Meek. Another remarkable feature of the fauna of the Comanche series is that the species have no affinities or resemblances in the other Cretaceous formations of the United States, while, on the other hand, they present remarkable analogies to certain well-known forms of other countries, especially eastern Europe and tropical America. This fact has always been so apparent, that many of the authors of species described from Texas (none of whom save Jules Marcou suspected their true paleontologic horizon), frankly confessed that they could distinguish no difference between the American and European forms, and gave them the same names, as in the case of the *Ostrea diluviana* Linne, White, the *Gryphœa sinuata*, var. *Americana* Marcou, and many of Roemer's and Shumard's species. The new names bestowed upon other forms were accompanied by expressed doubts as to their value, while nearly all the authors gave such close analogies that modern biologists would not hesitate to consider the differences varietal, and not specific.

A review of the fossils of the Comanche series shows that the Ammonitidæ, which are especially abundant in the Washita Division, consist of the sharp-keeled and flexuous-ribbed forms so characteristic of the Lower Cretaceous, while the genus Crioceras (Ancyloceras) is represented by several species absolutely indistinguishable from Neocomian forms. The characteristic *Ammonites pedernalis* Von Buch (not Binkhorst), of the Comanche Division, is an aberrant archaic ceratitic form. The only brachiopod of the Comanche series, which occurs about midway in the Washita Division, the *Terebratula wacoensis* Roemer, was confessed by its author to be very near *T. semiglobosa* Sow., of the Neocomian. The Echinodermata all belong to genera which had their origin in or previous to the Lower Cretaceous, and have great affinities to the European forms, one of which is almost indistinguishable from the characteristic *Toxaster complanatus*. The Ostreidæ mostly belong to the deep-water, and now extinct sub-genera Gryphæa, Exogyra, and Alectryonia, a great number of which present none of the confusing variation of the later Ostreidæ. The anomalous *Gryphæa Pitcheri*, which is an exception to the last generalization, instead of having been originally described from New Jersey and being the most widely distributed form of the Cretaceous in the United States, as has been asserted, was originally described from Indian Territory, and is almost if not entirely limited to the Comanche Series, except a few forms from the overlying shales of the Rocky Mountain region. This is a Jurassic form, which has continued up into the Cretaceous of this country, and the naviate variety is almost indistinguishable from the *G. arcuata* of the European Lias. It was chiefly upon the evidence of the *Exogyra texana* and the *Ostrea carinata* that Roemer made this Comanche series belong to the Upper Chalk of Europe, but according to modern biologic methods these forms really belong to two well-marked ostreidean types that have been described under a host of names, which have the widest vertical range of any Cretaceous forms, and the Texas individuals bear much greater resemblance to the basal varieties of the Neocomian than to those of the Chalk. The Caprotina of Roemer is the genus Requienia, characteristic of the European Lower Neocomian, and the widely distributed single species characteristic of the Fredericksburg Division of the Comanche series, which has been described under many synonyms, is hardly distinguishable from the characteristic *Caprotina Lonsdalii* D'Orb., of the European Neocomian. The Rudistes, Nerineas, Pleurotomarias, Globioconchas, and other forms, while not decisive, are corroborative of the low position of the Comanche series. This opinion is strengthened, furthermore, by the occurrence of many other forms, and the absence of any species characteristic of the upmost Cretaceous.

While the upmost strata of the Washita division have many species characteristic of the lower Middle Cretaceous of Europe,* I believe that there is no room to doubt that the deep marine fauna of the whole of the Comanche series shows a wonderful similarity to well-known forms of the European strata below the upper portions of the Middle Cretaceous, and bearing special resemblance, in its lower portion, to the Neocomian. The presence of Middle Cretaceous forms in the upper portion of the Washita division, near its transition into the Dakota sandstones, is confirmatory of Meek's opinion that the latter could not have been older than the upper portion of the Middle Cretaceous. Not only is the Comanche series older, but the faunal and stratigraphic breaks between it and the Upper Cretaceous are complete, and show in this a great similarity to the European Cretaceous, where, according to Etheridge, "of the total number of fossils from the 'Lower Greensand' or Upper Neocomian (upwards of 400) only 65 (or 16 per cent) pass to the Upper Cretaceous (chiefly to the Gault). This paleontological break with unconformity between the Lower Greensand and the Gault in the south of England, and the top of the Speeton clay and succeeding Red chalk or Hunstanton limestone in Norfolk, clearly show that a definite boundary line exists between the lower and upper parts of the Cretaceous system of England."

Dr. Ferdinand Roemer, after having accepted the erroneous stratigraphic theory, pointed out in the previous pages, that this series rested upon the Upper division, instead of unconformably beneath it, endeavored to make the paleontology fit this hypothesis, much to the obscuration of our Cretaceous geology. From the foregoing evidence, I believe there is room to doubt the correctness of his opinion that "the Cretaceous strata of Texas altogether belong to the Upper Chalk, i. e., the chalk above the Gault, and indeed so much so that they correspond to the horizon of the White Chalk ('Etage Senonien,' D'Orbigny), and to the upper part of the Chloritic Chalk ('Etage Turonien,' D'Orbigny) of Europe; but, in addition, include the lower or Neocomian."†

I have used the three divisions which a fortunate series of non-conformities have displayed at Austin, for the purpose of clearer contrast, but farther north in the Fort Worth and Denison region the sediments are more continuous from the first approach of the Mesozoic seas upon the Carboniferous continent as seen in the Dinosaur sands to the Marine Tertiary. This section reveals two transitions from littoral deposits of sands to deep-sea chalks and back again, the shallows of the Dakota (Lower Cross Timber) sands representing the medial stage.

* Juronien, of D'Orb. † Kreid. von Texas, p. 25.

It is probable that the present Austin New Braunfels nonconformity continued to Red river, and that future stratigraphic study will demonstrate this. It is nearly obliterated by a more excessive denudation there, but a portion of the old plateau exists in the Grand Prairie, between the Upper and the Lower Cross Timbers. This plateau is clearly the remnant of an elevation previous to the deposition of all the hitherto marine Cretaceous of America, although it was submerged again in parts, as is seen by the deposition of later formations upon it.

I have shown by methods of stratigraphic paleontology that we have in Texas not only the most complete section of the purely marine formations of the Cretaceous of the United States, but we have a well-defined series of marine strata of much lower horizon than heretofore supposed to exist in this country, which when they are properly studied, will eliminate the supposed hiatus of deposition which has been thought to exist between Jurassic or Wealden, and middle· upper portion of the Middle Cretaceous of this country. In fact, we have in Texas, along the region described in this paper, the most of a section of the Cretaceous and other Mesozoic which, from its approximate completeness, must in the future be looked upon as the standard of comparison in the study of the Mesozoics of this country, just as the Paleozoic formations of the Appalachian region are accepted as our standard for earlier time.

For the present we can only divide the American Cretaceous section into generalized Upper, Middle and Lower divisions. When, by modern methods of stratigraphic paleontology, this Texas region is more thoroughly studied, we shall have a simple comprehensive section of the entire period, which will serve as a standard of comparison, owing to its greater development and transitional geographic position for both the Rocky Mountain and Atlantic regions, and as a basis for an intelligible and rational nomenclature Until this is done all attempts at a fixed nomenclature of the American Cretaceous must remain unsatisfactory and provisional.

SCIENTIFIC INTELLIGENCE.

I. Physics and Astronomy.

1. *Annalen der Physik und Chemie*, No. 8[b], for 1887, contains the following articles; *On a new polar effect of magnetism upon the heat produced by the electric current in certain substances;* by Albert von Ettingshausen.—The author finds that a temperature difference obtains in a magnetic field and discusses the

bearing of this phenomenon upon the Hall effect. The paper includes a mathematical discussion of the subject by Boltzmann.

On the Electromotive force developed in metal plates, carrying a heat current, by a magnetic field; by WALTHER NERNST.—This paper is a continuation of the work of Ettingshausen, by a student in the laboratory of Kohlrausch.

On the effect of Magnetism upon electric discharges in rarefied gases by LUDWIG BOLTZMANN.—A flattened Geissler tube was placed with its broadest section perpendicular to the lines of magnetic force. Two glass tubes leading out of the magnetic field served to connect the electrodes of a galvanometer. The apparatus thus imitated the arrangement used by Hall in the investigation of his phenomenon. A transverse effect was discovered analogous to that in metals. Air behaved as bismuth or gold.

Observations upon the electrical conductivity of metals by means of the induction balance; by A. OBERBECK and J. BERGMANN.—The authors show that Hughes's balance in general is not a trustworthy instrument. Using an electro-dynamometer instead of a telephone, and thin plates of metal they obtained good results.

Theory of the induction Balance; by A. OBERBECK.—Mathematical discussion.

On the electrical conductivity of pure water and its temperature coefficient; by E. PFEIFFER.—The effect of the chemical constitution of the glass confining vessels is noted; also, change of resistance with time and other conditions.

Electrical relations of Rock Salt; by FERDINAND BRAUN.—Its dielectric constant is studied. It was found to behave as an isotropic substance in this relation. It conducts electricity from 11 to 23 times better than paraffine.

Studies of Salt Solutions; by C. BENDER.

Two fundamental investigations upon the laws of Pyroelectricity; by EDUARD RIECKE.

On Hydrogen superoxide arising in electrolysis of dilute sulphuric acid at the anode; by FRANZ RICHARZ.

On the applicability of Joule's law to electrolytes; by HANS JAHN.

Magnetic circular polarization in cobalt and nickel; by H. E. J. G. DUBOIS.

Gliding of the electric spark on the surface of water; by J. SPIESS.—This is a study of Lichtenberg's figures on the surface of water which is covered by lycopodium.

On the influence of ultra violet light on electrical discharges; by H. HERTZ.—The author shows that ultra violet light increases the striking distance and length of spark of a Ruhmkorff coil. If one draws apart the poles of a Ruhmkorff coil so that the spark no longer passes, and then lights an electric light from one to four meters distant, the spark again passes and stops, when the electric light is extinguished.

On the compressibility of dilute salt solutions; by W. C. RÖNTGEN and J. SCHNEIDER.

On the taking up of water vapor by solid bodies; by Dr. T. IHMORI.

On water of crystallization of dissolved cobalt salts; by JACOB KALLIR.

An answer to W. Voigt's remarks upon elliptical polarization of the reflected light of transparent bodies; by W. WERNICKE.

Projection of the true image of a vibrating string; by J. PULUJ.

Answer to the remarks of Franz Kolácèk on the freezing point; by ROBERT VON HELMHOLTZ.

Water of Crystallization; by W. MÜLLER-ERZBACH.

. *On the height of clouds;* by W. KOHLRAUSCH.—The author noticed a peculiar cloud and measured its height, obtaining a height of sixty kilometers. J. T.

2. *The production, properties and uses of very fine threads.*—The production of extremely fine threads of glass, quartz and other materials has been brought to a high degree of perfection by Mr. C. V. BOYS. The method which he found most satisfactory in its results was the following: a fragment of drawn out glass was attached by sealing wax to the tail of an arrow made of a piece of straw a few inches in length; the glass was heated to a high temperature in the middle and while the end was held in the fingers the arrow was projected by a cross bow of pine held in a vise and with a trigger that could be pulled by the foot. With every successful shot the thread was continuous from the piece held in the hand to the arrow 90 feet off, a glass thread 90 feet long and $\frac{1}{10,000}$ inch in diameter being obtained. The diameter was almost perfectly uniform for the greater part of the length. Instead of holding the glass tail in the hand, a little bead of glass may be fused on the end and, when the arrow is shot, the inertia of the bead is sufficient to draw out the thread in the same way.

The author has also experimented upon a number of minerals and found that while some behave like glass, others will not draw at all being either perfectly fluid like water or when cooler perfectly rigid. Thus corundum, hornblende, zircon, rutile, cyanite, fluorite will not draw at all; on the other hand emerald and almandine will draw but care is needed to obtain the proper temperature. Orthoclase draws readily, but quartz though troublesome and requiring more force yields remarkably successful threads of extreme minuteness, in some cases tapering down to a size beyond the power of the microscope to resolve. These minute threads have some peculiar properties which the author proposes to investigate, they are highly elastic and it is suggested that they may be advantageously used for torsion-threads. They may also be preferable to spider lines for the cross wires in the eye-pieces of microscopes and other instruments.—*Phil. Mag.*, xxiii, 489.

3. *Photography by Vital Phosphorescence.*—DR. JOHN VANSANT has continued his experiments in photography by phospho-

rescent light (this Journal, xxxiii, 307) and obtained the curious result of an image formed by the light from fire flies. A dozen of the fire flies were enclosed in a wide-mouthed vial, in which they emitted their momentary flashes of greenish-yellow light, in the familiar way, stimulated by a gentle shaking. A sensitive bromide dry plate was placed beneath an ordinary glass negative of a landscape, and the vial of insects inverted over the back of the negative. The plate was exposed to the light emitted by fifty of the flashes and then developed; a distinct positive image of the negative picture was the result, the plate being somewhat yellow stained as if from too long an exposure.—*St. Louis Photographer*, July, 1887.

4. *Annual Reports of the Board of Directors of the Chicago Astronomical Society, together with report of the Director of the Dearborn Observatory for* 1885 *and* 1886*; with papers by* Professors SAFFORD (*Nebulæ*), COLBERT (*Lunar apsides and Sirius*), *and* HOUGH (*Double Star Catalogue, and printing chronograph*). Chicago, 1887, pp. 50.—The work with the great equatorial of this observatory has been principally given to difficult double stars and the planet Jupiter.

5. Professor PICKERING has decided to publish short articles upon Astronomical and Meteorological subjects prepared at the Harvard College Observatory as successive numbers of a series which will constitute the 18th volume of the Annals of the Observatory.

The first article is a table of the magnitudes of the stars used in the various Nautical Almanacs. The table contains 800 stars, and gives their magnitudes derived from the Harvard, the Argentine, the Wolff and the Oxford Photometries. It will be of interest both to regular and to amateur astronomers as an independent catalogue of the brighter stars, and as an index to the stars in the several almanacs.

The second paper consists of a comparison of the Oxford, the Harvard and the Bonn Uranometries.

6. *Resultados del Observatorio Nacional Argentino en Córdoba durante la direccion del* D^{or} BENJAMIN A. GOULD; JUAN M. THOME, *Director*. Vol. VI, 4°, Buenos Aires, 1887.—This sixth volume contains the Cordoba observations made during the year 1875. The 7th and 8th volumes containing the zone catalogue have been already published.

II. GEOLOGY AND MINERALOGY.

1. *Damming and erosion by Greenland ice.*—Mr. J. E. MARR, in an interesting paper on the work of ice sheets as illustrated by the Greenland glacier (Geol. Mag., April, 1887), has the following paragraphs on the damming of valleys by ice, and the amount of erosion in some valleys.

The very conspicuous manner in which the Greenland valleys are stopped up by ice is also worthy of notice in connection with

the glacial theory of the origin of the Parallel Roads of Glenroy. The Jacobshavn glacier stops up both ends of a valley running parallel with its course, converting it into a lake which is separated from the glacier throughout the greater part of its length by a "Nunatak." The lower end of another valley considerably to the south of this is stopped by the ice-sheet, and the valley converted into a lake (Tasersiak), which is drained by a river running over the col at the head of the valley into the Strömfjord, just as in the case of the Märjelen See, only the Greenland lake is much larger than this. A similar lake drains into the N. Isortok fjord, and another into that of Alangordlia. Two similar lakes are formed to the east of Sermilik fjord, and several small ones to the east of Björnesund. North of the Frederikshaab glacier is a valley running north and south, the mouth of which is stopped by the Frederikshaab glacier, whilst a tongue of ice flows through a col situated half-way up the valley and bars the valley, one part of the tongue of ice flowing a small distance to the north, and another to the south, thus causing the conversion of the valley into two lakes. On the east of the Frederikshaab glacier is the lake Tasersuak, bounded on the north by the "Nunatak" Kangarsuk, and stopped at its lower end by the Frederikshaab glacier, and having a tongue of the ice-sheet entering into it at the upper end.

The erosive power of an ice-sheet is well seen by a glance at the observations made upon the rivers which flow into the fjords of Nagsugtok and Isortok, and which have their origin at the ends of the tongues of ice which occupy the valleys continuous with these fjords. The river from the first contained only 200–225 grams of mud per cubic meter of water in the month of July, while the second in the month of June enclosed 9129 to 9744 grams. This is compared with the amount carried by the Aar where it emerges from the glacier; it there contains only 142 grams. The great difference presented by the rivers which fall into the two fjords is attributed to the fact that the ice moves with much greater speed toward the fjord of Isortok than toward that of Nagsugtok. It is calculated that the quantity of fine mud carried into the former of these fjords amounts to 4062 million kilograms per day. This mud is deposited in the interior of the fjord, which is filled up to such an extent in its upper portion that even flat boats cannot pass up it. What a powerful machine for the formation of the fine clay of "till" is here.

2 *Variations in water-level in enclosed Seas.*—Professor Suess has recently discussed the phenomenon of variation in the relative heights of water and land, more especially for the Baltic Sea, and with reference to the different hypotheses that have been advanced to explain it. He decides in favor of the opinion held by Nordenankar, that the phenomenon is not due to elevation of the land but is essentially one of variations in the height of the water as caused by the varying precipitation and outflow. The

extended observations that have been made show that the oscillations in water-level go on with great uniformity, that they are more marked in the north, and that years with a positive average alternate with those with a negative, the latter being now in excess. Attention is also called to the fact that a similar conclusion has been reached for the Black Sea by Haun and Köppen. For the Mediterranean the conditions are somewhat similar, though here the amount of salt is greater than in the ocean, increasing in the neighborhood of Crete and the African coast, since the inflow of the streams through the Bosphorus and Gibraltar does not suffice to supply the place of the water evaporated. Accurate measurements of level have shown that the surface of the Mediterranean lies a little deeper than that of the ocean, it resembling somewhat a shallow funnel with greatest depth coinciding with the region where the water is most salt. A continual equilibrium is not to be expected but rather variations of the water condition especially toward the apex of the funnel. The greatest recorded changes of the coast-line are to the southwest of Crete, and amount to 20 to 23 feet (negative) as given by Spratt. Even on the Spanish and French coast where the amount of salt is almost the same with that of the ocean, variations of 0·4 to 1·02 meters have been recorded.—*Akad. Wien., Anzeiger*, xvi.

3. *Unconformability between the Animikie and the Vermilion Series;* by ALEXANDER WINCHELL. (Communicated to the Editors in a letter dated Aug. 20, 1887.)—I beg to announce that while engaged in work for the Minnesota Geological Survey, I have discovered the unconformable superpositions of the Animikie on the slates of the Vermilion series. The Animikie flint schists dipping five degrees southward, have been traced by me to within *seven feet* of sericitic argillites of the Vermilion series, dipping northeast about 67 degrees. I will communicate particulars hereafter.

4. *Catalogue of the Fossil Mammalia in the British Museum.* Part IV, containing the Order Ungulata, Suborder Proboscidea; by RICHARD LYDEKKER, B.A., F.G.S., etc. 236 pp. 8vo, with 32 woodcuts. London, 1886. — This volume completes Part IV. The collection of remains of the Proboscidea in the British Museum is without a rival, and this gives special importance to the annotated catalogue. The following *on the vertical distribution of the Proboscidea* is from pages xii, xiii.

The most remarkable point in regard to the vertical distribution of the Proboscidea is their apparently sudden appearance in the Middle Miocene of Europe, where they are represented by *Dinotherium giganteum* and *Mastodon angustidens*. Although the former is evidently a generalized form connecting the *Elephantidæ* with the less aberrant Ungulates, yet it cannot be regarded as the direct ancestor of any known member of that family; and the latter is to all intents and purposes a perfect Elephant, in the widest sense of that term. Our comparatively full knowledge of the Lower Miocene and Upper Eocene Mammalian faunas of the

greater part of Europe and North America (where the Proboscidea are unknown till the Pliocene) renders it almost certain that neither of those regions was the home of the direct ancestors of the *Elephantidæ*; and we must therefore look forward to the discovery of mammaliferous Lower Miocene or Upper Eocene strata in some other region of the (probably Old) World, which may yield these missing forms. There is, however, but little chance of the occurrence of such beds in India, and our main hope must therefore be directed to other parts of Asia, or Africa, if indeed these regions were ever populated in early Tertiary times by the larger Mammalia.

In regard to geographical distribution there appears to be considerable evidence in favor of an easterly migration of the Mastodons having taken place from Europe to India; while the restriction of the Stegodont group of Elephants to the latter country and the regions to the eastward, points to the conclusion that the transition from the Mastodons to the higher Elephants took place in those regions; from which we may also infer that there subsequently ensued a westerly migration of these higher forms to Europe, and finally on to North America, where the true Elephants did not make their appearance till the Pleistocene, and then appear to have been represented only by two species, one of which ranged over the greater part of the higher latitudes of the northern hemisphere.

5. *Mineral localities in the Western United States.*—At recent meetings of the Colorado Scientific Society various new occurrences of minerals have been described. Mr. W. B. Smith mentions the rare mineral dioptase from a new locality near Riverside, Pinal county, Arizona; it is found in well-formed prismatic crystals, the largest $3{\cdot}5^{mm}$ in length and $0{\cdot}5^{mm}$ in thickness. He also notes alabandite in crystals on Snake river, Summit county; manganite on Devil's Head mountain, Douglas county; a black ferriferous rutile from near St. Peter's Dome in the Pike's Peak region; epidote and garnet and a corundum schist from Chaffee county. Mr. R. M. Pearce describes the occurrence of enargite at the Gangon mine, Montana; erinite and other copper arsenates, also pharmacosiderite, from the Tintic district, Utah.

III. Miscellaneous Scientific Intelligence.

1. *British Association.*—The meeting of the British Association for 1887, opened at Manchester on the 31st of August. The number of tickets sold approached 4,000, exceeding the number of any former year. The grants to investigators during the past year aggregate more than $10,000. The proceeds available for the coming year from the large attendance at this meeting will be still greater.

The inaugural address of the president, Sir Henry E. Roscoe, alluded, in its opening remarks, to the honorable mention of the name of the great Manchester chemist, John Dalton, in the presi-

dential address of Lord Francis Egerton at the meeting in Manchester of 1842, and referred then to Joule, another Manchester philosopher, as the worthy successor of Dalton. Sir Henry then proceeded to consider "what light the research of the past fifty years has thrown on the subject of the Daltonian atoms: First, as regards their size; secondly, in respect to their indivisibility and mutual relationship; and thirdly, as regards their motions."

As to the size of atoms, Dalton believed them immeasurably small; but, in 1865, Loschmidt, of Vienna, reached the conclusion that the diameter of an atom of oxygen or nitrogen was 1/10,000,000 of a centimeter, and a few years later, William Thomson demonstrated that the distance between the centers of contiguous molecules is less than 1/5,000,000, and greater than 1/1,000,000,000 of a centimeter. As regards atomic weights, and the idea of hydrogen as a unit, conclusions of Dalton and Prout, the present position of science is that the weights in many instances are not exact multiples of hydrogen; and yet they are so near that "we are constrained to believe that the approximations cannot be a mere matter of chance; that there is a reason for it which science will yet discover." New relations between groups of elements also have been ascertained, as that which, through Mendelejeff, has proved to be prophetic of new discoveries of elements, and which has appeared to point to the conclusion that the elements have been derived from a common source. The indivisibility of atoms, assumed to be a fact by Dalton, has hence become a subject for investigation and argument. But actual division has not yet been accomplished by the highest terrestrial temperatures, that of the electric spark; nor has it been proved by the study of the sun's conditions, nor by the investigations of the spectra of the fixed stars; so that the idea of evolution of the elements is not yet proved. On this important point we cite here the words of the address.

"How far, now, has this process of simplification been carried? Have the atoms of our present elements been made to yield? To this a negative answer must undoubtedly be given, for even the highest of terrestrial temperatures, that of the electric spark, has failed to shake any one of these atoms in two. That this is the case has been shown by the results with which spectrum analysis, that new and fascinating branch of science, has enriched our knowledge, for that spectrum analysis does give us most valuable aid in determining the varying molecular conditions of matter is admitted by all. Let us see how this bears on the question of the decomposition of the elements, and let us suppose for a moment that certain of our present elements, instead of being distinct substances, were made up of common ingredients, and that these compound elements, if I may be allowed to use so incongruous a term, are split up at the temperature of the electric spark into less complicated molecules. Then the spectroscopic examination of such a body must indicate the existence of these common ingredients by the appearance in the spark-spectra of these elements of

identical bright lines. Coincidences of this kind have indeed been observed, but on careful examination these have been shown to be due either to the presence of some one of the other elements as an impurity, or to insufficient observational power. This absence of coincident lines admits, however, of two explanations—either that the elements are not decomposed at the temperature of the electric spark, or, what appears to me a much more improbable supposition, each one of the numbers of bright lines exhibited by every element indicates the existence of a separate constituent, no two of this enormous number being identical.

Terrestrial analysis having thus failed to furnish favorable evidence, we are compelled to see if any information is forthcoming from the chemistry of the sun and stars. . . . . .

"Since Bunsen and Kirchhoff's original discovery in 1859, the labors of many men of science of all countries have largely increased our knowledge of the chemical constitution of the sun and stars, and to no one does science owe more in this direction than to Lockyer and Huggins in this country, and to Young in the New England beyond the seas. Lockyer has of late years devoted his attention chiefly to the varying nature of the bright lines seen under different conditions of time and place on the solar surface, and from these observations he has drawn the inference that the matching observed by Kirchhoff between, for instance, the iron lines as seen in our laboratories and those visible in the sun, has fallen to the ground. He further explains this want of uniformity by the fact that at the higher transcendental temperatures of the sun the substance which we know here as iron is resolved into separate components. Other experimentalists, however, while accepting Lockyer's facts as to the variations in the solar spectrum, do not admit his conclusions, and would rather explain the phenomena by the well-known differences which occur in the spectra of all the elements when their molecules are subject to change of temperature or change of position.

"Further, arguments in favor of this idea of the evolution of the elements have 'been adduced from the phenomena presented by the spectra of the fixed stars. It is well known that some of these shine with a white, others with a red, and others again with a blue light; and the spectroscope, especially under the hands of Huggins, has shown that the chemical constitution of these stars is different. The white stars, of which Sirius may be taken as a type, exhibit a much less complicated spectrum than the orange and the red stars; the spectra of the latter remind us more of those of the metalloids and of chemical compounds than of the metals. Hence it has been argued that in the white, presumably the hottest, stars a celestial dissociation of our terrestrial elements may have taken place, whilst in the cooler stars, probably the red, combination even may occur. But even in the white stars we have no *direct* evidence that a decomposition of any terrestrial atom has taken place; indeed we learn that the hydrogen atom, as we know it here, can endure unscathed the inconceivably fierce

temperature of stars presumably many times more fervent than our sun, as Sirius and Vega.

"Taking all these matters into consideration, we need not be surprised if the earth-bound chemist should, in the absence of celestial evidence which is incontestable, continue, for the present at least, and until fresh evidence is forthcoming, to regard the elements as the unalterable foundation-stones upon which his science is based."

Another new contribution to the question of the decomposability of the elements is that made by Crookes, who, by means of the spectra of the phosphorescent light of some rare earths under an electric discharge in a vacuum, ascertained the possible presence of new elements, showing, as in the case of yttria, either that the bodies yielding the different phosphorescent spectra are different elementary constituents of the substance which we call yttria; or, in consideration of their yielding the same spark-spectrum, "adopting the very reasonable view that the Daltonian atom is probably, as we have seen, a system of chemical complexity, and to this adding the idea that these complex atoms are not all of exactly the same constitution and weight, the differences, however, being so slight that their detection has eluded our most delicate tests with the exception of this one of phosphorescence in a vacuum." A third possible explanation is suggested by Marignac—the presence of traces of foreign bodies, introduced in the course of the thousands of separations which have to be made before the differences become manifested. Dalton showed that gases diffuse into one another; and Graham later, but over fifty years since, that the relative rates of diffusion are inversely proportional to the square roots of their densities. But Joule, in his papers on the mechanical equivalent of heat, and on the constitution of electric fluids, expressed the movements in figures, and established "the foundation of chemical dynamics and the basis of thermal chemistry; and he added the further fact that "when electrical energy is developed by chemical change a corresponding quantity of chemical energy disappears." Another step onward, in the direction of electrical chemistry has been taken in establishing the fact that an intimate relation exists between chemical activity and electrical conductivity.

Dalton was the first to point out the existence of distinct compounds consisting of the same constituents in the same percentage quantity. On this as a starting point, the science of organic chemistry has been built up through the addition of the principle as to the combining capabilities of elements, or their valency, the nature and relations of radicals, and the principle of substitutions. Further results have come from consequent advances in organic synthesis. Sir Henry Roscoe treats briefly also of the progress made in the theory of animal heat and other questions connected with pathological chemistry.

This brief abstract of the presidential address is made from the full report of it in *Nature* of September 1. *Nature* of September 8,

(the last number thus far received), contains the address of Sir Robert Hall, president of the Physical Section, on "that part of the science of theoretical mechanics, which is usually known as the Theory of Screws," under the title "A Dynamical Parable"—that of Edward Schunck, Ph.D., president of the Chemical Section—on the directions in which the chemistry of the future will probably be developed, under which he spoke of facts and problems in the physiology of plants, and others relating to the decomposition of organic and organized matters and ferments; and that of Henry Woodward, F.R.S., president of the Geological Section, reviewing the field of research in geology, and pointing out some of the special needs of the science.

2. *Memoirs of the National Academy of Sciences;* Vol. III, Part 2.—This volume, recently issued, contains the following papers: Contributions to meteorology, by Elias Loomis, pp. 1–66, with 16 plates; On Flamsteed's stars "observed but not existing," pp. 69–83, and Corrigenda in various star catalogues, pp. 87–97, by C. H. F. Peters; Ratio of meter to yard, by C. B. Comstock, pp. 101–103; composite photography as applied to craniology, by J. S. Billings, and on measuring the cubic capacity of skulls, by W. Matthews, pp. 105–116 with 20 plates; on a new craniophore for use in making composite photographs of skulls, by J. S. Billings and W. Matthews, pp. 119–120, 4 plates; on the Syncarida, pp. 123–128, 2 plates, on the Gampsonychidæ, pp. 129–133, 1 plate, and on the Anthracaridæ, by A. S. Packard, pp. 135–139, 2 plates; also on the Carboniferous xiphosurous fauna of North America by the same author, pp. 143–157, 4 plates; on two new forms of polyodont and gonorhynchid fishes from the Eocene of the Rocky Mountains by E. D. Cope, pp. 161–165, 1 double plate; notes on the third memoir, page 45, part 1, by A. M. Mayer.

3. *Smithsonian Institution and the Fish Commission.*—It is expected that Professor Langley, who for the past year has been the Assistant Secretary in the Institution, will be made Secretary. Mr. G. Browne Goode has been appointed Commissioner of the Fisheries and no better appointment could have been made.

OBITUARY.

Spencer Fullerton Baird, the Zoologist, the Commissioner of the Fisheries under the U. S. Government, and the Secretary of the Smithsonian Institution, died at Wood's Holl, Massachusetts, on the 19th of August.

Mr. Baird was born at Reading, Pennsylvania, in the year 1823. He graduated, in 1840, from Dickinson College, at Carlisle, Pa., and five years later, in his twenty-third year, was made Professor of Natural History in that Institution. When but fourteen he made, in connection with his brother, Wm. M. Baird, a collection of the birds of Cumberland Co., Pa., manifesting thus early that zeal for natural science which determined his future course in life; and in 1844, the two published, in this Journal, a list of the Cumberland County birds, having in view,

as the authors say, the bearing of such publications of local faunæ on the laws which regulate the distribution of species on the globe. This paper is followed by another on two new species of Tyrannutæ from the same region.* Mr. Baird's collection of birds, fishes, mammals, etc., became greatly extended by long excursions on foot in the Adirondacks and elsewhere which his great powers of physical endurance enabled him to carry on and for distances, some days, of nearly 60 miles.

The writer first made the acquaintance of Mr. Baird in 1843, when working over the corals of the Wilkes Exploring Expedition, then arranged in the hall of the Patent Office; and he had for some time daily proof of his enthusiasm in science, his earnestness as a worker, his scientific knowledge and his generous disposition—the latter manifested, among other ways, in his gift of a translation of Ehrenberg's Memoir on the Corals of the Red Sea, which he had in the meantime prepared. This was the commencement of his interest in the Expedition collections that afterward came under the charge of the Smithsonian Institution when he was assistant Secretary.

Professor Baird's appointment to the position of assistant Secretary in the Institution was made in 1850. It was hailed with great satisfaction by those interested in the natural sciences; for it was thus made sure that the Institution, which had so admirable a representative of the physical sciences in the secretary, Professor Henry, would be ably conducted as regards other scientific departments. It was just the place for him and he was just the right man for the place. His breadth of knowledge in the sciences of nature, his sympathy with other workers over the land, his indefinite powers of work, his systematic methods, and his eagerness to make the Institution national in the highest sense of the term and also scientifically and practically useful, produced their effects; and happily there was full support of the assistant secretary in his views and plans by Professor Henry. Part of these plans consisted in the furthering of Government explorations for scientific discovery and observations in the Territories; and for many years after 1850 such expeditions were in the field adding greatly to the knowledge of the structure, features, resources, floras and faunas, etc., of the country, and gathering specimens for a great national museum. The arrangements and selection of men for such expeditions, were largely in Mr. Baird's hands, and much of the success attending them was due to his wisdom. The gathering of specimens finally resulted in 1857, in the union of the collection with those of the Wilkes Exploring Expedition in a common museum, supported by funds from the General Government but under the charge of the Smithsonian Institution.

Dr. Baird's study of American birds led to his commencing in 1846 the preparation of a Synonymy of North American Birds;

* Cited from the Proceedings of the Academy of Natural Sciences of Philadelphia, vol. i, 1843.

and, later, to various publications, among them a "Catalogue of North American Birds," published by the Smithsonian in 1858–1859; a "Review of American Birds in the Museum of the Smithsonian Miscellaneous Collections," begun in June, 1864; a Memoir on the "Distribution and Migrations of Birds," presented to the National Academy in 1865, and printed in abstract (covering 31 pages) in volume xli (second series, 1866) of this Journal; and in conjunction with Mr. John Cassin, "The Birds of North America," issued in 1870; and, along with T. M. Brewer and R. Ridgeway, an illustrated work on the Birds of North America, in 1874. In the department of fresh-water fishes of North America a work was projected by Professor Agassiz and himself soon after the arrival of the former in the country, but nothing of it was ever published.

Dr. Baird also published papers on Reptiles, and in 1853 "an Annotated catalogue of North American Reptiles" was issued by Mr. C. Girard and himself, which contained descriptions of several new species of serpents. His publications on Mammals also were numerous, and included, in 1859, a volume of 764 pages quarto on "the Mammals of North America," several of whose two hundred and twenty species were before undescribed. An early laborious work, finished in 1851, was his "translation" of the text of the "Iconographic Encyclopedia," making four large volumes—which work as regards the second volume was "entirely re-written," the Botany, Fishes, Amphibians, Reptiles and Anthropology by himself, the Invertebrates by S. S. Haldeman, the Ornithology by John Cassin and the Mammals by C. Girard.

While carrying on his investigations and writing books and papers, he found time also for the multitudinous details connected with the Smithsonian Institution, its extended system of exchanges, the fitting out of exploring expeditions, the writing of his part of an annual Smithsonian report, and so on. To these duties were added in 1871, by appointment of the President of the United States, but without additional remuneration, those of Commissioner of Fisheries; and the practical working and success of this new department under the government attests to his wide knowledge and his executive ability. As another has said, "the services he rendered in this capacity in increasing the food-supply of the world would alone justify a national monument to his memory."

In 1878, on the decease of Professor Henry, Mr. Baird was appointed his successor as Secretary of the Institution, a place for which he was eminently fitted by his long and active experience in its affairs.

Professor Baird's large contributions to science brought him medals and honorary membership from various scientific academies abroad; and the connection of his name with thirty-three new genera and species of animals attests to the high appreciation of him by fellow-workers in zoology.

Incessant labor finally wore upon his health. "For some years he appears to have fully recognized the fact that his day as an active investigator was over, and he had contented himself with directing others. When he was sent as advisory counsel by the United States to the Halifax Fish Commission he prepared an essay on fish culture into which he threw all the wealth of his vast information and experience on this subject. He kept that manuscript unpublished, hoping to add to it, but recently put it in the press, and it is now in course of being printed, and will be a posthumous contribution of inestimable value to the history of the pursuit to which he gave so much time and attention. In like manner he lately placed the results of his ornithological studies in the hands of Professor Ridgeway, and they are now in course of publication by a leading Philadelphia firm. His life is rounded and his career has closed with a record of achievements that will grow in public estimation the more it is contemplated."

When he went in June last, to Wood's Holl, the chief summer station under the Commission of the Fisheries, he was much broken in health; and, although he rallied for a while, but a few weeks passed before the end came. His wife and his daughter survive him.

ALVAN CLARKE died on the 22d of August at Cambridge, in his eighty-fourth year, having been born at Ashfield, Massachusetts, March 8, 1804. The science of astronomy owes much to Mr. Clarke. Through his skill and judgment, dependent largely on delicacy of touch and sight, and the promptings of astronomical zeal started up by the discovery of some new double stars made with an instrument of his own construction, he became famous as a maker of telescopes, and had orders, more than he could fill, from foreign as well as American observatories. His discoveries led to correspondence with the English astronomer, Mr. W. R. Dawes, and afterwards to some years of study abroad between 1850 and 1860. His first large telescope, 18½ inches in diameter of object-glass is in the observatory at Chicago; one of 26 inches at the U. S. Observatory, Washington; another of the same size, at the Observatory of the University of Virginia; one of 32 inches, at the Pulkowa Observatory, Russia; and one of 36 inches at the Lick Observatory of California. The Russian telescope brought him a gold medal from the Czar. The manufacture of telescopes has been carried on by him in connection with his sons, George B. and Albert Graham Clarke, who have like skill and perfection of work.

APPENDIX.

ARTICLE XXXV.—*Notice of New Fossil Mammals;* by O. C. MARSH.

AMONG the large number of extinct mammals recently received at the Yale Museum from the West, are several of especial interest, as they serve to mark definite horizons in the Tertiary deposits east of the Rocky Mountains, or show important characters not before observed. A notice of some of these species new to science is given below, and more complete descriptions will appear elsewhere.

Bison alticornis, sp. nov.

This species of Bison is represented by various remains, the most important of which is the portion of a skull, figured below. This specimen, which may be regarded as the type, indicates one of the largest of American bovines, and one differing widely from those already described. The horn-cores, instead of being short and transverse, as in the existing bisons, are long and elevated, with slender, pointed ends. They have large cavities in the base, but in the upper two-thirds are nearly, or quite, solid. Their position is well shown in the cuts below, figures 1 and 2. The frontal region between the horn-cores is broad, somewhat convex, and very rugose.

FIGS. 1 and 2.

FIGURE 1.—Part of skull, with horn-cores, of *Bison alticornis*, Marsh; front view.
FIGURE 2.—The same specimen; seen from the left.
Both figures are one-eighth natural size.

The remains of this species are found in the sandstones of the Denver group, at the eastern base of the Rocky Mountains, where they indicate a well-marked horizon, which may be called the Bison beds. These deposits are more recent than the Equus beds, and are probably late Pliocene.

The locality of the type specimen is on the banks of Green Mountain Creek, near Denver, Colorado, where it was found by George L. Cannon, Jr., of Denver. Portions of the same specimen were subsequently secured by Whitman Cross of the U. S. Geological Survey. Other remains were obtained by G. H. Eldridge of the Survey, and all were sent to the writer for examination.

Aceratherium acutum, sp. nov.

Remains of the present species are abundant in one horizon of the Pliocene east of the Rocky Mountains, and a large number of fine specimens have been secured, which are now

FIG. 3.

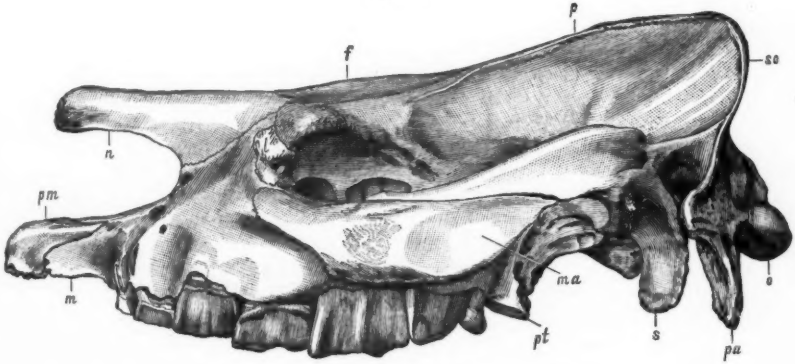


FIG. 4.

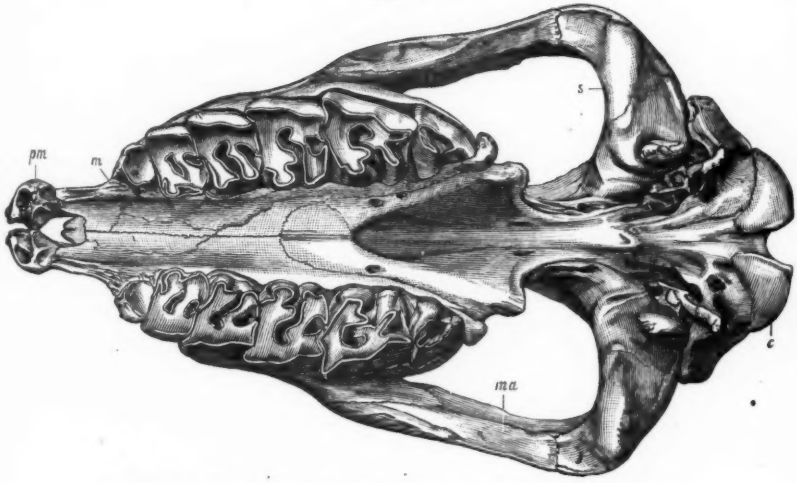


FIGURE 3.—Skull of *Aceratherium acutum*, Marsh; seen from the left.
FIGURE 4.—The same specimen; seen from below.
Both figures are one-fifth natural size.

in New Haven. The skull represented above, in figures 3 and 4, has been selected as the type. It is narrow at the base, with widely expanded zygomatic arches, and with the facial portion

tapering rapidly in front. There is a well-marked sagittal crest, and a strong constriction between the temporal openings. The frontal bones expand rapidly forward, and meet the broad, smooth nasals, which converge anteriorly into the pointed ends which have suggested the specific name. The paroccipital process is strong and elongate, and the post-glenoid is shorter and more massive. The premaxillary bones are weak, and project considerably beyond the end of the nasals. They each supported a single incisor.

A striking feature of the skull is the very large size of the molar teeth, which are well shown in figure 4.

There were no lower jaws found with the present skull, but in other specimens of this species, they are well represented. Each ramus is of moderate depth, the angle rounded, and the lower border gently convex below. On each side of the symphysis is a small incisor, and outside of this, a large, worn tooth, which is probably a canine. There is a short diastema, and behind this, are six robust teeth.

The locality of these remains is in Phillips County, Kansas, and the special horizon in which they occur so abundantly is in the Pliohippus beds of the Upper Pliocene. The specimens here described were obtained by J. B. Hatcher of the U. S. Geological Survey.

Brontotheridæ.

The large collections of the *Brontotheridæ* secured by the writer in his various expeditions in the West have been supplemented by important discoveries made during the last two years, mainly under the auspices of the U. S. Geological Survey. Remains of more than one hundred individuals, many of them with the skulls in good preservation, have recently arrived in New Haven, and are now under examination. The results of an investigation of the whole group will be brought together by the writer, in a monograph now well advanced toward completion. Some of the more important of the new forms are briefly described below, and these will all be fully illustrated in the monograph.

Brontops robustus, gen. et sp. nov.

The present genus is quite distinct from any of the forms previously described, and the type is the most perfect specimen of this group yet discovered. The skull and lower jaws are almost as perfect as in life, and the greater part of the skeleton has also been secured. The skull is large and massive, with widely expanded zygomatic arches, and short and robust horn-cores, projecting well forward. In general form, it resembles

the skull of *Brontotherium*, but may be readily distinguished from it by the dental formula, which is as follows:

Incisors $\frac{2}{1}$; canines $\frac{1}{1}$; premolars $\frac{4}{4}$; molars $\frac{3}{3}$.

The presence of four premolars in each ramus of the lower jaw is a distinctive feature in this genus. This character, with the single, well-developed incisor, marks both the known species.

The type species here described is one of the largest of the group, and the skeleton on which it is based is already represented on many plates of the monograph in preparation. The skull is about thirty-two inches (81 cm.), in length, and twenty-six and one half inches (67 cm.), across the zygomatic arches. The pelvis is over four feet (120 cm.), in width.

This unique specimen was discovered by the writer and H. C. Clifford, his guide, in 1874, near the White River in northern Nebraska. The geological horizon is in the upper part of the Brontotherium beds of the Lower Miocene.

FIG. 5.

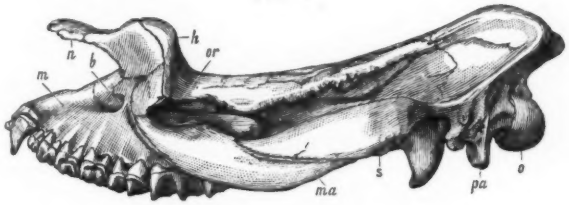


FIG. 6.

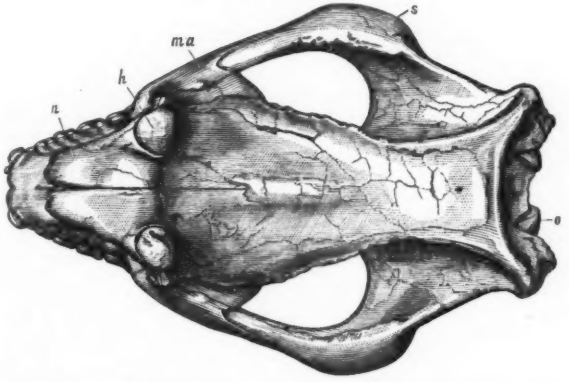


FIGURE 5.—Skull of *Brontops dispar*, Marsh; side view (young male).
FIGURE 6.—The same skull; top view.
Both figures are one-eighth natural size.

Brontops dispar, sp. nov.

A smaller species of this genus is represented at present by a nearly complete skull with lower jaws and entire dentition. The skull is less massive, and proportionately more elongate than in the type species, and the lower jaw more slender. The latter is shown below, in figures 7 and 8, which also illustrate some of the generic characters.

The skull of a young animal, apparently of this species, is represented in figures 5 and 6. The sutures are many of them distinct, especially those in the facial region, and thus the elements of the horn-cores, in this genus at least, can be readily determined. The front of the elevation is formed by the

FIG. 7.

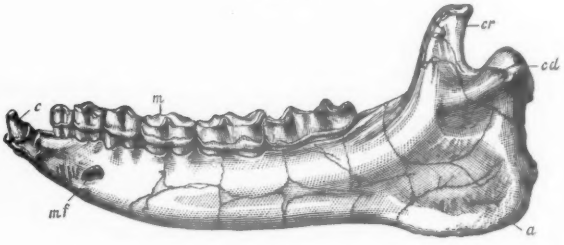


FIG. 8.

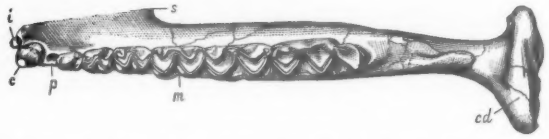


FIGURE 7.—Lower jaw of *Brontops dispar*, Marsh; side view.
FIGURE 8.—The same jaw; top view.
Both figures are one-eighth natural size.

nasal, and the main portion by the frontal. The maxillary contributes only the outer face of the base, but in some of the other genera, its share appears to be larger.

The specimens above mentioned were found in the Brontotherium beds of Dakota, by Mr. J. B. Hatcher of the U. S. Geological Survey.

Menops varians, gen. et sp. nov.

The present genus is most nearly related to *Diconodon*, and in its molar teeth agrees with that form. It differs in the

presence of two upper incisors on each side. The superior dentition is as follows:

Incisors, 2; canine, 1; premolars, 4; molars, 3.

In figure 9, below, is shown the type specimen, which is evidently the skull of a large adult male. Figure 10 represents a female skull apparently of the same species. The latter skull is much less robust, and the horn-cores are very small, although the dentition and sutures show that the animal was fully grown.

FIG. 9.

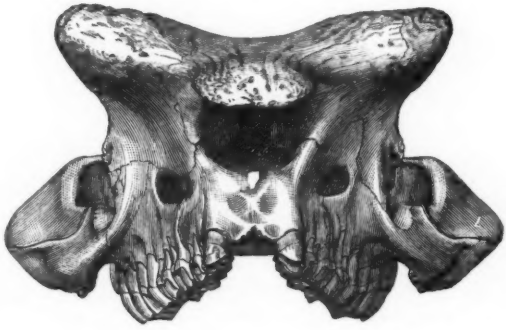


FIG. 10.

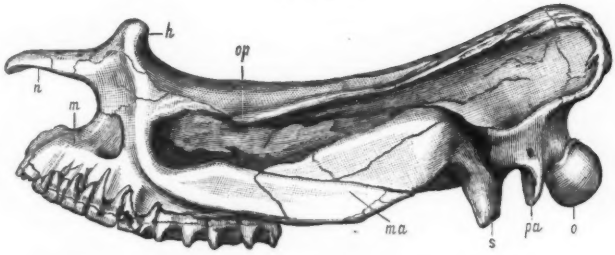


FIGURE 9.—Skull of *Menops varians*. Marsh; front view (male).
FIGURE 10.—Skull of same species; side view (female).
Both figures are one-eighth natural size.

The interesting specimen shown in figure 9 was obtained by Mr. George A. Clarke, from the Brontotherium beds of Dakota. The other specimen was found in the same region by Mr. J. B. Hatcher.

Titanops curtus, gen. et sp. nov.

This genus contains the largest members of the *Brontotheridæ*, and some of the last survivors of the group. They are distinguished from all the other known types, by the long, narrow skulls, lofty, flat horn-cores, and short nasals. The upper dentition corresponds nearly to that of *Brontotherium*, but the upper molars have all two inner cones.

FIG. 11.

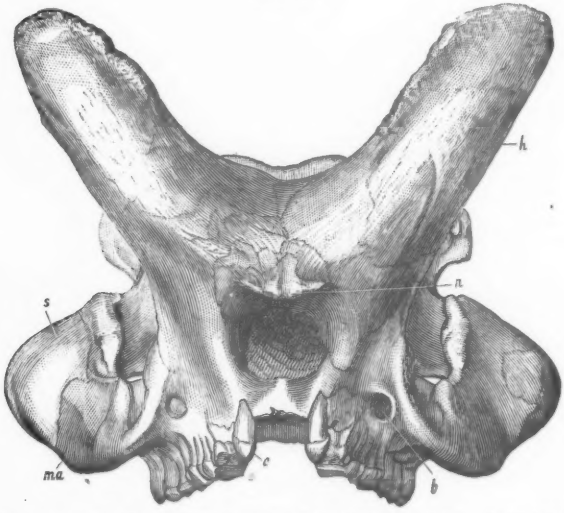


FIGURE 11.—Skull of *Titanops curtus*, Marsh; front view. One-eighth the natural size.

Figure 11 shows the front view of the type specimen, which indicates well the above features. The nasals are the shortest known in the group.

This specimen was obtained by the writer, in the lower Miocene of Colorado.

Titanops elatus, sp. nov.

A second specimen, about equal to the last in size, but representing a different species, is shown in figure 12. The nasals are much longer, and the occipital crest much higher, than in the type species. The zygomatic arches are unfortunately wanting, but the lower jaw is present, nearly in place. It shows no marked characters different from that of *Brontops*.

This specimen is from the Miocene of Dakota, and for important aid in securing it, the writer is indebted to Prof. F. R. Carpenter of the Dakota School of Mines.

FIG. 12.

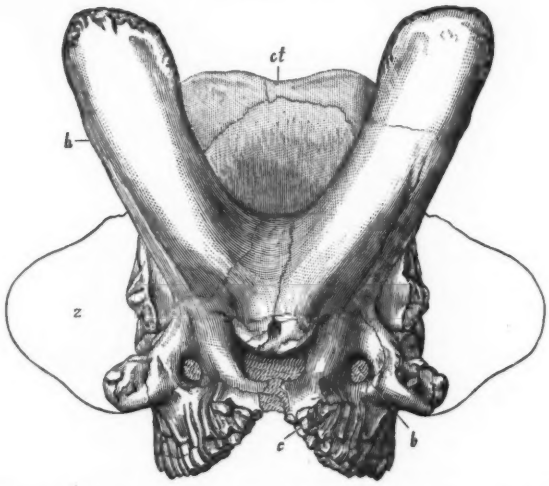


FIGURE 12.—Skull of *Titanops elatus*, Marsh; front view. One-eighth the natural size.

Allops serotinus, gen. et sp. nov.

Another genus nearly related to *Brontotherium* is represented at present by a well-preserved skull, and various other remains. This skull in its general form resembles that of *Brontotherium*, but differs in having only a single upper incisor, and the last molar has the posterior inner cone more strongly developed.

The superior dentition is as follows:

Incisor, 1; canine, 1; premolars, 4; molars, 3.

In the type specimen, the canine is small, extending but little below the premolars. There is no diastema. The upper premolars have a very strong inner basal ridge. The nasals are very wide, expand forward in the free portion, and are notched in front.

The entire length of this skull is thirty-one inches (79 cm.), the distance across the zygomatic arches twenty-one inches (53 cm.), and the length of the horn-cores about ten inches (25 cm.)

This specimen was found near the top of the Brontotherium beds in Dakota by Mr. J. B. Hatcher, who has done much by his discoveries to increase our knowledge of this group.

Yale College, New Haven, Sept. 24th, 1887.

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ERRATA.

Vol. xxxiv, page 227, line 12 from top, for MOREHEAD read MORELAND; line 30, for single read *simple;* line 32, for required read *acquired.*